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OF THE

IRON AND STEEL INSTITUTE.

ANNUAL MEETING, 1891.

WEDNESDAY, MAY 6TH.

The Annual Meeting of the Institute was held to-day at the Institution of Civil Engineers, 25 Great George Street, London—Sir James Kitson, Bart., President, in the Chair.

The Minutes of the previous General Meeting were read, confirmed, and signed by the Chairman.

The Report of the Council for 1890 was then submitted.

REPORT OF THE COUNCIL FOR THE YEAR 1890.

The year 1890 has been notable in the history of the Institute in respect of the large increase that has been made to our membership. The total number of new members elected in 1890 was 174; 72 at the Spring, and 102 at the Autumn meeting. This is a much larger number than has been elected in any previous year, and it is interesting to add that it is within 11 of the total number of original members elected in 1869, the year of the foundation of the Institute. The most prosperous year, judged by the standard of increase of membership, next to 1890, was 1875, when 144 new members were elected; and next to that again came 1873, the year of the Belgian meeting, when 134 names were added to the list. Since the foundation of the Institute the total number of members elected has been 2487, including the 185

original members in 1869; and as the total number at present on the roll is 1573, it appears that 914 members have died, retired, failed to take up their membership, or been removed from other causes. The tabular Appendix to this Report shows the numbers that have been elected at each meeting since the Institute was established.

Twenty-eight members have been removed from the list during the year 1890, so that the net increase of membership has been 146. Fifty members have been proposed for election at this meeting, as compared with 72 at the annual meeting of 1890, and 54 at the corresponding meeting of 1889.

During the past year the following deaths of members of the Institute have taken place, viz.:—

Samuel Anderson, Westbury.	Joseph Musgrave, Bolton.
Albert Cole, Brierly Hill.	Thomas Page, West Bromwich.
John Corner, London.	Lewis J. Pirie, Cape Colony.
John Fleming, Newcastle-on-Tyne.	James Stewart, Glasgow.
Alfred C. Hill, Southbank.	Chas. Wells, Wednesbury.
John Hughes, Hughesoffska, Russia.	B. Willett, Paris.

Within the last few weeks the Council has had to deplore the death of Mr. Benjamin Walker, of Leeds, one of their number, who has been a regular attender at the meetings of the Institute for many years. They would also refer to the death of Mr. Robert Mushet, one of the first to whom the Bessemer gold medal of the Institute was awarded, and well known in respect of his association with the Bessemer and other metallurgical processes.

A number of changes have been made in the composition of the Council during 1890, involving the retirement of several of the older members, and their replacement by Professor Roberts-Austen, of the Royal Mint and the Royal School of Mines, Mr. R. A. Hadfield, of Sheffield, and Sir William Thomas Lewis, of Cardiff, as English members; while Mr. Andrew Carnegie, of Pittsburgh, and Mr. Alexander Thielen, of Ruhrort, have been elected to represent the United States and Germany, respectively. The Council feel sure that the new departure which has been made, in admitting to the Council representatives of countries that furnish such important contributions to our list of members as those last named, will have the full approval of the members generally.

The following papers were read at the two general meetings of the Institute, held in London and New York, respectively, during 1890:—

At the London Meeting.

On Some Critical Points in Iron and Steel. By Mons. F. OSMOND, Paris.

On the Carburisation of Iron by the Diamond. By Prof. C. ROBERTS-AUSTEN, F.R.S., London.

On Aluminium in Carbonised Iron. By Mr. W. J. KEEP, Detroit, U.S.A.

On the Changes in Iron Produced by Thermal Treatment. By Dr. E. J. BALL, London.

On Certain Chemical Phenomena in the Manufacture of Steel. By Mr. W. GALBRAITH, Wingerworth.

On the Estimation of Phosphorus in the Basic Siemens Steel Bath. By Mr. W. GALBRAITH, Wingerworth.

On the Rollet Process for Producing a Pure Carbide of Iron. By Mons. ROLLET, Paris.

At the New York Meeting.

On the Development of American Blast Furnaces, with Reference to Large Yields. By Mr. JAMES GAYLEY, Pittsburgh.

On the Bessemer Steel Process. By Mr. HENRY M. HOWE, Boston, U.S.A.

On the Thomson Electric Welding Process. By Professor THOMSON, New York.

On the Manufacture of Spirally-Welded Steel Pipes in the United States. By Mr. J. C. BAYLES, New York.

On the Iron Development and Ore Resources of Virginia. By Mr. E. C. PECHIN, Cleveland, Ohio.

On Fuel Gas and Some of its Applications. By Mr. B. LOOMIS, Hartford, Connecticut.

On the Wear of Metal, as Influenced by its Chemical and Physical Properties. By Dr. CHARLES B. DUDLEY, Altoona, Pennsylvania.

On Testing Materials of Construction in the United States. By Messrs. HUNT and CLAPP, Pittsburgh.

In addition to the foregoing, the following papers were contributed, through the Council of the Institute, to the International Meeting held at Pittsburgh :—

On the Probable Future of the Manufacture of Iron. By Sir LOWTHIAN BELL, Bart., F.R.S., Middlesbrough.

On the Protection of Iron and Steel Ships against Foundering from Injury to their Shells, including the Use of Armour. By Sir NATHANIEL BARNABY, K.C.B., London.

On the Development of the Marine Engine, and the Progress made in Marine Engine Construction during the past Fifteen Years. By Mr. A. E. SEATON, M.I.C.E., M.I.M.E., M. Council, I.N.A., Hull.

The autumn meeting of the Institute for 1890 was held in the United States. In their last Report, the Council intimated their belief that there was every prospect of the then forthcoming meeting on American soil being "alike instructive, agreeable, and successful." This anticipation has been realised to the fullest extent. More than 300 members of the Institute accepted the invitation to meet in the United States, and they were accompanied by about 50 ladies. The regular Autumn meeting of the Institute was held in New York on the forenoons of the 1st, 2nd, and 3rd days of October. The afternoons of the same days were devoted to visits and excursions. After paying visits to Philadelphia on October 4th and 5th, and subsequently to Cornwall, Altoona, and Johnstown, Pittsburgh was reached on the 8th of that month, and on the 9th and 10th an International Meeting was held in the Carnegie Hall of Allegheny city, in which the Iron and Steel Institute, the American Institute of Mining Engineers, and the Verein Deutscher Eisenhüttenleute took part. The proceedings at both the New York and the Pittsburgh meetings passed off satisfactorily, and both are likely to be long remembered for the cordiality of the reception accorded to the Institute, and for the profuse hospitality shown on all hands.

The most notable feature of the visit of the Institute to the United States was the two excursions organised for the purpose of enabling members to see the iron-making resources of the Southern States, and the iron and copper regions of the Lake Superior region, respectively. Both excursions started from Chicago on the evening of Tuesday, the 14th day of October, and, after re-assembling at Washington eleven days later, and visiting Niagara Falls, terminated at New York on the 28th of October, having thus extended over fourteen days. During a great part of this time, the members had to eat and sleep on board the trains, but the arrangements were carried out with so much forethought and care that this necessity was attended with little real discomfort. The President, in a letter to Mr. W. P. Shinn, who was the head of the Committee on Transportation, suitably expressed the general opinion of the members of the party when he said :—

"This great expedition of the members of the Iron and Steel Institute was probably the most numerous party that ever attempted so extended and complicated a tour. Thanks in large measure to your skilful direction and powers of organisation, the whole series of visits, enterprises, and public functions was carried through completely, in absolute safety, and without a drawback."

The American meeting of the Institute has not only been especially interesting for the interchange of courtesies, and the comparison of experience and practice, between the metallurgists of the two continents, but it has been productive of a much more extensive series of papers and discussions than has ever before been published by the Institute in respect of any autumn session. The regular volume of the *Journal* (No. II., 1890), containing the reports of the New York meeting of the Institute, and of the Pittsburgh International Meeting of the three societies already named, contains about a thousand pages of technical matter. This is by far the largest volume of "Proceedings" that the Institute has hitherto issued. The diagrams illustrating the papers read at New York and Pittsburgh, have been similarly unique, numbering nearly sixty plates, besides numerous drawings and cuts in the text, making the volume as a whole the most largely illustrated of any hitherto published. The Council, in calling attention to this subject, would add that they are fully persuaded that the quality of the contributions that make up this large volume will be found at least equal to that of the former "Proceedings." This conclusion, they think, will be endorsed by the members generally, in view of the fact that the principal contributions have been written by such high authorities as Sir Lowthian Bell, Sir Nathaniel Barnaby, Dr. Hermann Wedding, Mr. R. A. Hadfield, Mr. James Gayley, Dr. Dudley, &c.

The numerous visits and excursions made by the members during their stay in the United States appeared to the Council to call for a special description and record. It was manifestly impossible that such a record could have been adequately attempted in our regular "Proceedings," having regard to the dimensions that they had already attained. It was consequently decided to issue a special American number of the "Proceedings," which should take the form of a memorial volume, and should embrace not only descriptions of the numerous mines, works, and other places of interest visited throughout the stay of the party in the United States, but also special descriptive and critical papers by experts. The Council are pleased to be able to

add that Sir James Kitson and Sir Lowthian Bell have undertaken to make contributions to this volume, which is now well in hand, and which will no doubt be found an interesting souvenir of a very memorable occasion.

While the Council took steps to convey to those who had borne the burden of the organisation of the reception and entertainment of the Institute their most cordial thanks for the services so ungrudgingly and successfully rendered, they felt that some more permanent and tangible tokens of appreciation would not only be justified, but would also be in the highest degree suitable to such an occasion. They accordingly appointed a Committee of their number, with the President at its head, to consider what form the intended presents should take. The Committee, with the fullest approval of the Council, made the following selections :—

For Mr. W. P. SHINN (*Chairman of the Committee on Transportation*), a pair of silver five-light candelabra, and a pair of silver candlesticks to match.

For Mr. J. F. LEWIS (*Chairman of the New York Reception Committee*), a chased silver two-handled bowl on ebonised pedestal, and a pair of smaller bowls.

For Mr. C. KIRCHHOFF, jun. (*Secretary to the New York and General Reception Committees*), a silver two-handled cup and cover, on pedestal.

For Dr. R. W. RAYMOND (*Secretary to the American Institute of Mining Engineers*), a silver inkstand, and a pair of Corinthian column candlesticks.

In forwarding these presents to the gentlemen named, the President conveyed to them, in suitable terms, the high appreciation of their services and exertions entertained by the Council and by the members who had been privileged to take part in the meetings and excursions in the United States. The acknowledgments that have since been received have fully satisfied the Council that the well-merited compliment paid to those gentlemen has been very highly appreciated.

In their last Report the Council announced that they had ordered the preparation of an Index to the "Proceedings" of the Institute since 1882, which was the date of issue of the last General Index, carrying the "Proceedings" up from 1869. The new Index is now ready, and it may be purchased by members for 2s. 6d. The "Proceedings" of the Institute are now fully indexed up to the end of the year 1889, a fact

upon which members may be congratulated. The Council propose to charge 2s. 6d. for each copy of the Index, believing that this small sum will not be grudged by members who really appreciate its utility as a help to research.

Retiring Members of Council.

As announced at the New York meeting, the retiring members of Council for 1890 were :—

Vice-Presidents.

Sir James Ramsden. Mr. E. Windsor Richards.
Mr. G. J. Snelus.

Members of Council.

Lord E. Cavendish. Mr. J. Cunninghame.
Mr. J. D. Ellis. Mr. S. R. Platt.
Mr. Benjamin Walker.

The Council have already referred to the decease of the last-named gentleman, in whose place they have elected Mr. Arthur Keen, of Birmingham. The other retiring members, in the absence of further nominations, are proposed for re-election.

APPENDIX.

NUMBERS OF MEMBERS ELECTED IN EACH YEAR SINCE 1869.

Elected up to June 1869		185	185
Members elected at London, June 23, 1869		44	
" "	Middlesbro', September 22, 1869	72	
" "	London, December 2, 1869	35	
	Total for 1869		151
" "	London, May 11, 1870	30	
" "	Merthyr-Tydvil, September 6, 1870	33	
	Total for 1870		63
" "	London, March 28, 1871	37	
" "	Dudley, August 29, 1871	47	
	Total for 1871		84
" "	London, March 19, 1872	29	
" "	Glasgow, August 6, 1872	80	
	Total for 1872		109
" "	London, April 19, 1873	65	
" "	Belgium, August 18, 1873	69	
	Total for 1873		134
" "	London, May 6, 1874	64	
" "	Barrow, September 2, 1874	62	
	Total for 1874		126
" "	London, May 5, 1875	84	
" "	Manchester, September, 1875	60	
	Total for 1875		114
" "	London, March 28, 1876	19	
" "	Leeds, September 18, 1876	50	
	Total for 1876		69
" "	London, March 20, 1877	26	
" "	Newcastle, September 17, 1877	34	
	Total for 1877		60
" "	London, March 28, 1878	47	
" "	Paris, September 16, 1878	38	
	Total for 1878		85
" "	London, May 7, 1879	24	
" "	Liverpool, September 24, 1879	58	
	Total for 1879		82
	Carry forward		1,292

	Brought forward		1,292
Members elected at	London, May 5, 1880	75	
" "	Düsseldorf, August 25, 1880	40	
	Total for 1880		... 115
" "	London, May 4, 1881	55	
" "	London, October 11, 1881	65	
	Total for 1881		... 120
" "	London, May 10, 1882	68	
" "	Vienna, September 10, 1882	54	
	Total for 1882		... 122
" "	London, May 9, 1883	71	
" "	Middlesbro', September 18, 1883	60	
	Total for 1883		... 131
" "	London, April 30, 1884	63	
" "	Chester, September 23, 1884	27	
	Total for 1884		... 90
" "	London, May 6, 1885	46	
" "	Glasgow, September 1, 1885	32	
	Total for 1885		... 78
" "	London, May 12, 1886	71	
" "	London, October 6, 1886	11	
	Total for 1886		... 82
" "	London, May 24, 1887	30	
" "	Manchester, September 14, 1887	34	
	Total for 1887		... 64
" "	London, May 9, 1888	71	
" "	Edinburgh, August 21, 1888	23	
	Total for 1888		... 94
" "	London, May 8, 1889	54	
" "	Paris, September 24, 1889	71	
	Total for 1889		... 125
" "	London, May 7, 1890	72	
" "	New York, October 1, 1890	102	
	Total for 1890		... 174
	Total Number of Members elected		2,487

Financial Statement for 1890.

Mr. David Dale (Hon. Treasurer) submitted the Financial Statement for 1890 (*vide* p. 228).

New Members.

Messrs. Charles Wood and W. C. P. H. Schroller were appointed scrutineers of the voting-papers, and reported, on the completion of their scrutiny, that the following candidates for membership had been duly elected:—

Adams, Geo. North	Wolverhampton.
Allan, George	London.
Borner, Herman	Bishopsgate Street, London.
Burrows, Thomas	Sheffield.
Butler, Joseph G., jun	Youngstown, Ohio, U.S.A.
Cayley, Claude Thornton	Old Broad Street, London.
Cole, Eugene Maurice	New York, U.S.A.
Colquhoun, William	Tredegar, Monmouthshire.
Coventry, Ernest	Laurence Pountney Hill, London.
Cowan, James Henry	Brent House, Woolwich.
Crebbin, Alfred	Pittsburgh, Pa., U.S.A.
Darby, Alfred	Wrexham.
Darley, Edward Charles	Pittsburgh, Pa., U.S.A.
Deegun, Thomas	Pittsburgh, Pa., U.S.A.
Duncan, Hon. Geo. A. P. H	Boston, Mass., U.S.A.
Evans, William	Oak House, Blaenavon.
Flett, John	Leadenhall Street, London.
Garnier, Jules	Rue de Berlin, Paris.
Gray, Matthew	West Hartlepool.
Griffin, Thomas Augustus	Chicago, U.S.A.
Hartshorne, Joseph	Pottstown, Pa., U.S.A.
Hoffstott, F. N	Pittsburgh, U.S.A.
Hollingworth, Edward	Dobcross, nr. Oldham.
Horsfield, J. H. H	Edinburgh.
Howat, William	Glasgow.
Kerr, John	Leadenhall Street, London.
Kirchhoff, Chas., jun.	New York, U.S.A.
Krupp, F. A	Essen, Rhenish Prussia.
Lewis, Herbert Clark	Aberdare, Mon.

LODGE, J.	South Pittsburgh, Tennessee, U.S.A.
MAHON, REGINALD HENRY	St. James' Street, London.
MALCOLM, SAMUEL	South Shields.
MASON, JAMES FRANCIS	Witney, Oxon.
McKILLOP, J.	Singapore.
McKNIGHT, H. WARTON	Pittsburgh, Pa., U.S.A.
McNEIL, CHAS., jun.	Glasgow.
MITCHELL, JOSEPH	Mitchell's Main, Yorkshire.
MITCHELL, JOSEPH	Sydney, New South Wales.
NICHOLAS, EVAN	Merthyr Tydfil, South Wales.
NOBLE, HENRY A.	Seattle, Washington State, U.S.A.
PRIESTMAN, ALBERT	Hull.
REECE, ROBERT THOMAS	Aberdare.
ROBINSON, THEO. W.	Wisconsin, U.S.A.
ROPER, ROBT.	Banner Cross, Sheffield.
SERVICE, ANDREW GRAHAM	St. Vincent Place, Glasgow.
STEVENSON, JOHN LESTER	Pittsburgh, Pa., U.S.A.
THOMPSON, WILSON	Glasgow.
TILLEY, ALBERT	Bilbao, Spain.
VOSMAER, ALEXR.	The Hague, Holland.
WARDALE, JOHN DOBSON	Gateshead-on-Tyne.

The PRESIDENT said he rose with great satisfaction to perform his last official task as President of the Institute, namely, to move, "That the report of the Council and the statement of accounts for the year 1890 be, and are hereby, adopted." He moved the resolution with satisfaction, because he knew that he was vacating his seat in favour of a gentleman who was of distinguished scientific position, but who also possessed habits of order and administration, which ensured that he would conduct the affairs of the Institute with advantage to all. He also felt satisfaction in moving the resolution, because it gave him an opportunity of thanking all his friends—he thought he might reckon amongst them all the members of the Institute—with whom he had come in contact during the past two years. Those years had been somewhat remarkable in the annals of the Institute. He would recall for a moment the visit to Paris and to the

French Exhibition. It would be remembered that they had expeditions to Le Creuzot and the Loire, as well as to the northern iron districts of France. Everywhere in France they were received with the utmost cordiality, and everything that it was possible to lay open to their inspection was readily shown to them. He referred to this, because it was possible that their late and more extended visit to the United States might perhaps have obscured the memory of that brilliant visit to the French Exhibition. Of course that was not the time to make any extended reference to the visit to America, since they would shortly have a special volume dealing with that expedition. Sir Lowthian Bell was very far advanced in an extensive survey of the iron industries in the Southern States, and other members were contributing an account of the resources of the North. It was impossible to say too much of the reception which their American friends gave them. Mr. Carnegie, when he received them on behalf of the American Iron Trade in New York, promised that everything should be laid fully open to their inspection, and that all information which they desired should be given to them. That promise was fulfilled to the letter. They had endeavoured, as would have been gathered from the Report, to make some complimentary acknowledgment to those officials who were particularly active in their service, and he thought that the testimonials to Mr. Shinn, Mr. Lewis, Dr. Raymond, and Mr. Kirchhoff, had been worthy of them and of the Institute. Probably the members had seen that an endeavour was made to mitigate the incidence of those testimonials on the funds of the Institute, by an appeal to the Treasury of the United States; but the Treasury was anxious that they should enjoy to the fullest measure the sacrifices that they were prepared to make, and the application that they made, in the interest of strict Protection, was not acceded to. They learned a great deal from their visit to the United States. Among other things, they learned, what was probably known to many of them, that the resources there were boundless, and that whether under Protection or Free Trade, the United States was bound to develop those resources, and to continue to be, in the course of its expansion, a great manufacturer of iron and steel. It seemed to him that the community at large in the United States would be much better for free and

open competition, but those who controlled these things there had the power of sustaining a different policy.

He wished to utter one word of warning as to the price of fuel. In the United States they found that coal was abundant and accessible. Both coal and coke were at a very much lower price there than in this country, and it appeared to him that producers and workmen at home, who now had the control of the cost of fuel, should pause in their demands in view of those illimitable resources of the United States.

It was a pleasant reflection to him, in relinquishing the chair, to know that during the last year of his office, more members had joined the Institute than in any other year since its formation. In 1869, the first year of its existence, there were 185 members, while 174 joined in 1890, so that last year they had nearly as many new members as they commenced with in the first year of their establishment.

They had lost by death several distinguished members. Amongst them he thought it right to name their honorary member, Earl Granville, who was a frequent attender at the annual meetings of the Institute, and always took a lively and courteous interest in its development, and in the conduct of its affairs. Mr. Mushet was also well known as having contributed most materially to the development of the remarkable invention of Sir Henry Bessemer; and he would like to make a passing reference to an old friend, Mr. Benjamin Walker, who only recently was elected a member of the Council. Mr. Walker was the genial friend of a large number of members, and there was no doubt that as a manufacturer of machines for the production of iron and steel, he had rendered material services.

Before sitting down he would like to call attention to the bust of Mr. Thomas which had been presented to the Institute by Mr. Pink, who was also the modeller of the bust. Those who knew Mr. Thomas said that it was a fair likeness of him, and it would be placed in the Council Chamber of the Institute.

It was probable that the autumn meetings would be held in the Midland Counties. It was well, after wandering so long in foreign climates, that they should return once more to their native home. He had good reason to hope that they would

receive an invitation to hold the autumn meeting in Birmingham, where they had not met since the year 1871.

When he addressed the Institute two years ago, he ventured to utter a few words of caution to manufacturers of iron and steel. They were then at the beginning of what looked like a great boom, and a long period of prosperity. He was afraid that during the last few months those hopes and anticipations had been somewhat chequered, and it was quite evident that the English manufacturers would require in the future to hold their position in the iron and steel trade of the world with the aid of all the knowledge and intercommunication of ideas that could be obtained through the Institute. He was quite confident, having regard to the fact that the numbers of the members of the Institute were greater than ever before, that the Institute would continue to do a great work, and in vacating the chair he had the satisfaction of knowing that he was doing so to Sir Frederick Abel, who was distinguished as a scientific man, and who had devoted much thought and research to the manufacture of iron and steel. He thought it was well that the rule, which was unwritten but understood, that the practical manufacturer should have his turn with the scientific man, should be followed, and he hoped that when the scientific man vacated the chair, another practical man might be found to succeed Sir Frederick Abel, who, he trusted, would, during his reign, be as happy as he himself had been in seeing the Institute so prosperous and so widely honoured.

Mr. Edward H. Carbutt said it was his pleasing duty to second the motion for the adoption of the report. His only complaint was that he had to second a motion which had been so ably moved by Sir James Kitson. As an outside member, not on the Council, he thought there was every reason to be satisfied with the report presented. During the two years' chairmanship of Sir James Kitson, the Council had done excellent work, and had been very energetic in looking after the interests of the Institute committed to their charge. He thought that was sufficiently proved by the very large addition to the members of the Institute. If it had been a mistake to go to France or to America, there would not have been such an

accession of members. The result showed that when the Council had the energy and industry to organise such an expedition as that to America, the members generally were willing to second their efforts in that direction. He believed that the visit to America had done good, both to the Institute and to the Americans. The question of free trade *versus* protection would have to be fought out, and the views of the members of the Institute on the subject would be of benefit when the time for discussion arrived. He was glad that Sir James Kitson was not dismayed by the large deposits of iron ore and coal in America. He had, however, struck a useful note of warning in recommending small economies in every branch of manufacture, improved machinery, and scientific research, in order that they might maintain their position, and be able to compete with foreign countries. England, as a small island, was greatly dependent upon its foreign trade, and it was necessary that our people should be kept well informed of the requirements of foreign countries, and enabled to live; and the only way in which that could be done was to keep English trade in its present position —at the head of the world. In the future it would not be a question of making very large profits, but of making a large turn-over with a small amount of profit. The Council of the Institute filled an important position in the country. It was hampered by no narrow rules. It admitted any one who by his ability could be of any use to the iron and steel trades,—metallurgists, scientific chemists, electricians, engineers, and practical manufacturers; and if such men put their heads together they could not fail to do some good in improving the general position of the trade. They had among them men like Sir James Kitson, Sir Lowthian Bell, Sir James Ramsden, Lord Edward Cavendish, Mr. Windsor Richards, and others who were willing (as in the case of their visit to America) to make great sacrifices for the benefit of the Institute and the trade. The past year had been a red letter one for the Institute, and they were all greatly indebted to the gentlemen who had done so much to maintain the position of England, and to show that her manufacturers were not dismayed, but were glad to meet their friends in the discussion of questions tending to the improvement of the iron and

steel trade. They had also to thank the Treasurer for his efforts. Mr. Dale was so urbane and courteous that he had not a single enemy. But he wished to utter a note of warning as to the £8000 in the Treasurer's hands. It was a mistake for an Institution to keep such a large balance. Instead of keeping it for building, he hoped that some of it would be spent in experiments and research. With reference to building a home for the Institute, he believed that the future would be able to take care of itself.

The Report of the Council and the Financial Statement for 1890 were then adopted.

LORD ARMSTRONG, C.B., proposed "That the best thanks of the Iron and Steel Institute be, and are hereby, tendered to the President, the Council, and the Hon. Treasurer for their services during the past year." He should have preferred seeing the resolution placed in the hands of a member who had been more frequent in his attendance, and made himself more intimately acquainted with the proceedings of the Institute; but he assured the meeting that his non-attendance had arisen from no want of interest in the proceedings, but from sheer inability, through advancing age, to attend the meetings of learned and other societies. It was evident that the work of the Institute would not have been so successful as it had been but for the vigorous and energetic management of the Council. He was very glad that the Institute had exhibited such great vitality and promise for the future, a circumstance largely due to the excellent management during the past year.

MR. W. H. WHITE, C.B., said he had much pleasure, as a junior member of the Institute, in seconding the motion proposed by Lord Armstrong. Mr. Carbutt had really anticipated much that he (Mr. White) might have properly said as to the work which the President and members of the Council had done in behalf of the Institute; but he had omitted one fact to which attention should be directed. Those members who stayed at home, and had not the opportunity of visiting America and seeing the marvels of that country, had deeply sympathised with the President and those

who accompanied him when they read from day to day of the great receptions, champagne luncheons, and banquets which were taking place; and the home-staying members were glad to find that they had returned home apparently none the worse for those great efforts, and were still living to assist in the development of the Institute.

The motion having been unanimously adopted,

The PRESIDENT said he was greatly obliged for the vote of thanks which the members had been good enough to pass. He once heard a distinguished speaker say that he liked to feel nervous before making a speech, because he always put more spirit into it and took more pains. He confessed that he felt very nervous when it was proposed to him to take the chair of the Institute; but he assured the members that his nervousness and anxiety had really constrained him to put forth his best efforts in conducting the business of the Institute with efficiency, and, he trusted, with dignity, during the past two years. He felt that they had made a great stride in their international visits, and that they had made friendships which would last their lives. He also felt that during his two years of office not the least of his compensations had been the friendships which he had been able to make with members of the Council, and members of the trade, whom otherwise he should not have met, and he hoped that it would be his good fortune in years to come to cement and to extend those most valuable friendships. It was now his duty to vacate the chair in favour of his successor.

Sir FREDERICK ABEL then took the chair, and delivered his Address.

PRESIDENTIAL ADDRESS.

BY SIR FREDERICK ABEL, K.C.B., D.C.L., D.Sc., F.R.S.,
President of the British Association.

YOUR selection of my late most highly esteemed and much lamented friend, Dr. Percy, to the honourable office of your President, was welcomed by his colleagues in the pursuit of chemical science as being a well-earned tribute to the eminent position attained by him as a scientific metallurgist, and as constituting an official acknowledgment, by British representatives of the iron and steel industries, of the valuable work in the interests of these which he accomplished. Would that equally substantial grounds existed in justification of the choice which you have made upon the present occasion, or that I might venture to ascribe my advancement to the proud position of President of one of the most prosperous and important societies representative of technology, to any other incentive on your part than a desire to furnish fresh public testimony of the high esteem in which those who are constantly labouring to advance and perfect the manufacture of iron and steel, and the adaptation of these to important uses, hold their fellow-labourers whose aim it is to apply pure scientific research to the attainment of fresh knowledge regarding the nature and properties and the rationale of production of those materials, and to the solution of such intricate problems connected therewith as still remain subjects for speculation or fruitful sources of rival theories.

A critical examination into the value of such claims as I may possess to take prominent rank among those who have, by actual work, promoted the advancement of the great industries of iron and steel, has carried me back to a period when those who, in this country, appraised at their proper value the services which the analytical and scientific chemist could render to the iron-master and the manufacturer of steel, might be counted upon the fingers, and when the first engagement, by a few of the more prominent British iron-masters, of well-trained young analytical chemists, to carry on at their works the systematic examination

of ores, fuel, and products, was an important indication of advance, presenting a strange contrast to the mystery which for years afterwards still surrounded the operations of many Sheffield steel-makers.

A comparison of the contents of that remarkable volume of papers on iron and steel published by David Mushet in 1840, embracing his original communications to the *Philosophical Magazine* in the first part of this century, with Sir Lowthian Bell's classical work on the manufacture of iron and steel, affords most interesting illustrations of the influence which the rapid development, diffusion, and intelligent application of chemical knowledge within the last half-century has exercised upon the extension and perfection of these industries; an influence co-equal with that exerted by the mechanical and physical sciences, to which the metallurgist is indebted for his power of utilising the results of chemical inquiry.

Systematic mineral analysis, the foundation of which was laid within the period of my early studies by the work and teachings of such illustrious men as Berzelius, Heinrich Rose, and Liebig, was just in process of thorough application in this country; volumetric analysis was altogether in its infancy, and spectroscopic analysis was not even dreamt of, when some three or four fellow-students of mine left their matchless teacher, Hofmann, to take rank amongst the earliest trained analytical chemists whose aid was sought by the iron-master, and whose co-operation, as analysts, soon contributed importantly to the establishment of a proper control over the quality of materials used in the blast furnace, and to the attainment of an accurate knowledge of the kind and extent of modification in composition of the furnace-products, brought about by variations in the nature, and the proportions used, of these materials, and of an acquaintance with the conditions attendant upon their treatment in the furnace.

When first, as the youthful successor to the illustrious Faraday in the Professorship of Chemistry at the Royal Military Academy, not very long before the outbreak of our war with Russia, it became my ambition to demonstrate the value of the analytical and scientific chemist's work in connection with the manufacture of war material, and with the proper housing, clothing, and equipment of the soldier, the metallurgic operations in the Arsenal at

Woolwich were limited to the production of small castings of brass for fittings of gun-carriages, and to the casting of bronze ordnance for field-service, which had been carried on at a foundry in Moorfields until 1716, when the services of an experienced Dutch founder, Andreas Schalch, were secured by the Government, and a foundry for brass ordnance was established in the Warren at Woolwich, afterwards named the Royal Arsenal. Our supplies of cast iron ordnance for siege and naval use were drawn from a very few of our most renowned iron-works, such as those of Carron, Low Moor, and Gospel Oak, and our shot and shell were also exclusively supplied from private works.

In those days our most powerful weapons were the 68-pounder or 8-inch 95 cwt. smooth-bore gun, used with a charge of 18 lb. of powder, which threw a spherical cast iron shell of about 48 lb. weight, containing 2 lb. 9 oz. of powder; and the 13-inch cast-iron sea-service mortar, used for bombardment, for which the spherical shell weighed 207 lb., and the projecting charge was 20 lb. of powder. The positions which these pieces then held are now occupied by the 8-inch rifled howitzer, throwing a conoidal wrought iron or steel shell, charged with a much more powerful explosive than powder; the 12-inch breech-loading gun of 45 tons weight, with a charge of 295 lb. of powder, throwing a projectile of 682½ lb. weight; the 80-ton 16-inch muzzle-loading gun, with a charge of 450 lb. and a projectile weighing 1640 lb., and the 110-ton breech-loading gun of 16¼ inches calibre, which throws steel projectiles weighing 1800 lb. with a powder charge of 960 lb. The cost of production of the smooth-bore cast iron guns in those days ranged from £25 to £30 per ton; now, our rifled steel breech-loading guns cost us from £170 to £200 per ton.

During the Crimean War, more than one disastrous experience with some of our armaments, supplied by contract during great pressure, led to the adoption by Government of the proposal to establish Government foundries and factories in the Arsenal for the production of guns and projectiles, and it was with the view of selecting suitable varieties of cast iron for the production of ordnance and projectiles that a very extensive analytical examination of ores, fuel, and fluxes, and of samples of iron produced

from these at various works in the United Kingdom, was carried out under my direction in 1856–58, together with a series of mechanical experiments with the metal cast under conditions practically identical, and cooled in various ways.

The series of analyses resulting from this inquiry served to give completeness to the valuable account of the composition of British iron ores, &c., which is included in Dr. Percy's celebrated manual, and which owes its origin to the munificence of the late Mr. S. H. Blackwell of Dudley, in presenting to the Museum of Practical Geology the extensive series of British ores which he prepared for exhibition in the first World's Fair of 1851.

The analyst has been indefatigable since that time in his strivings to devise and to perfect processes for the expeditious and accurate valuation of ores, and for the attainment of trustworthy results in the complete determination of the composition of ores and products; and it is not easy to over-estimate the importance of the laborious investigations continually undertaken by the analytical expert with the object of promoting and facilitating the attainment of uniformly concordant results by different analysts in determining the composition of an ore, not merely with respect to its richness, but especially with regard to components likely to affect more or less importantly the treatment which it is to receive and the quality of metal which it may furnish. In my earlier student's days, forty-five years ago, one of the most difficult test-problems set to the young analyst, after the completion of his course of practical study, was the complete analysis of a sample of chrome iron ore; and even with the great advance which has been made since then in methods of analytical investigation, the attainment of closely concordant results in the examination of such an ore, by different operators of experience, is by no means to be relied upon. Even in the determination of the proportions of carbon, phosphorus, or manganese, in a sample of iron or of steel which may contain those elements in only very small proportions, discrepancies of moment between the results of different operators are still liable to occur, consequent either upon the employment of different methods of analysis, or upon personal peculiarities of the analyst.

The consideration of this important subject was entered upon by the British Association at its meeting in Bath in 1888, at the

instigation of Professor J. W. Langley, of Michigan University, who reported that he had, in conjunction with Professor Herman Wedding and Professor Åkerman, considered a general plan of operations having for its object the promotion of greater uniformity in analysis in the countries which are the principal producers and users of iron and steel; the proposal being to prepare a series of absolutely identical samples, to distribute these for analysis among highly qualified operators selected in different countries, the results being afterwards compared, and to deposit portions of the samples in those countries as international standards, which might be utilised at any time for testing or controlling the accuracy of individual work, in cases of importance, or for testing the value of new analytical processes. It was decided by the Association to appoint a committee of English experts to co-operate with Professor Langley and his associates in other countries, and this committee prepared a number of suggestions with reference to the preparation of a series of five samples of steel, containing, as nearly as possible, specified total proportions of carbon ranging from 1·3 to 0·07 per cent.; the samples to be sufficiently large, after providing material for the required analyses by the selected referees, to allow of the deposition of about 10 lb. of each standard in each of the different countries interested; the samples to be subdivided into series of small specimens, hermetically sealed in glass tubes, so that portions should be available for supply to applicants without detriment to the remainder of the samples. These suggestions were approved, and have been acted upon as closely as possible, the material for the standards and the mechanical work having been supplied gratuitously by the Crescent Steel Works of Pittsburgh.

The samples were despatched to their several destinations in the summer of 1889, and the experts selected for the conduct of their analysis in England have, I believe, almost completed the work assigned to them.

Some departure from the course of action agreed upon appears to have been adopted in the United States; the committee of chemists there appointed to carry out the analyses, in view of existing differences of opinion regarding the trustworthiness of accepted methods of determining the carbon in steel, resolved

that it was desirable to institute, in the first instance, a preliminary experimental study of the chief methods in use for estimating that constituent, and the results of this investigation were communicated to those attending the International Metallurgical Congress at Pittsburgh in October last by Professor Langley, during the recent visit of members of this Institute to the United States. That instructive communication furnished an interesting illustration of the importance of exhaustive investigations, by competent and thoroughly reliable authorities, into the comparative merits of different processes applied to analytical research.

A method of examination of iron and steel, to the probable value of which the attention of chemists and metallurgists was first directed, at any rate in this country, by Dr. Sorby, more than a quarter of a century ago, and which, in the hands of that expert experimenter Dr. Herman Wedding and others, has furnished very instructive results, consists in the microscopic inspection of carefully prepared sections of the metal, their structure being in the first instance developed by treatment with a weak acid. The employment of such a chemical agent for bringing to light the actual structure of a metal surface which has been disguised by the process of planing or of polishing is, it need scarcely be said, of much earlier date, and there are interesting illustrations of this in Faraday and Stodart's paper on the alloys of iron and steel, published in 1820. They commenced their investigations by analysing Wootz or Indian steel; they satisfied themselves that it owed its peculiar character to the presence of very small quantities of the earths silex and alumina or their metals, and after having prepared small quantities of carbonised iron, containing about 5·5 per cent. of carbon, they mixed this with pure alumina, heated the mixture intensely in a closed crucible, and thus obtained a white brittle alloy which appears to have yielded 6·4 per cent. of alumina, and from which, by fusion in small quantities together with good steel, they produced a perfectly malleable metal. Upon forging this into little bars, polishing their surfaces, and treating them with dilute sulphuric acid, they obtained the beautiful damask surfaces peculiar to Wootz—a result reproduced by a repetition of the experiment.

Percy ascribed the damasked pattern exhibited on the surfaces

of Damascus sword-blades solely to the production of these from material manufactured by piling and welding together bars of steel and iron, and then drawing the masses out under the hammer or otherwise, so that when their polished surfaces are submitted to the action of an acid, the surface of the iron filaments enclosed in the mass are left with a white or bright appearance, while the steel portions assume a dark colour, due to firmly adherent carbonaceous matter which has been eliminated by the acid. But Faraday and Stodart pointed out, in 1820, that while damasked surfaces may certainly be produced upon masses obtained by welding together wires of iron and steel, if the welded specimens be fused, this property disappears, whereas they ascertained by repeated experiment that the Indian steel called Wootz, although repeatedly fused, retains the peculiar property of presenting a damasked surface when forged, polished, and acted upon by a dilute acid.

They add that "supposing the damasked surface (of Wootz) is dependent on the development of a crystalline structure, then the superiority of Wootz in showing the effect may fairly be considered as dependent on its power of crystallising when solidifying, in a more marked manner, and in more decided forms, than the common steel. This can only be accounted for by some difference in the composition of the two bodies, and as it has been stated that only the earths in small quantities can be detected, it is reasonable to infer that the bases of these earths" (*i.e.*, silicon and aluminium), "being combined with the iron and the carbon, render the mass more crystallisable, and that the structure drawn out by the hammer and confused (though not destroyed), does actually occasion the damask. It is highly probable that Wootz is steel accidentally combined with the metals of the earths, and the irregularity observed in different cakes, and even in the same cake, is in accordance with this opinion. The earths may be in the ore, or they may be derived from the crucible in which the fusion is made."

I have quoted at length this description (in which both the language and the logical mind of Faraday are clearly recognisable), because there is a distinct analogy between it and the description recently given by Hadfield of the effect of aluminium in increasing the size of the crystals, and opening the grain, of iron

with which it is alloyed. Although the discovery by Faraday and Stodart of very estimable quantities of aluminium and silicon in Wootz, and in the steel made as described, which possessed the properties of Wootz, may be in part ascribable to the possibility of those impurities having been derived from the materials or implements used in the analytical operations (a source of error upon which much stress has been laid in recent discussions at our meetings), the uniformity and peculiarity of the results obtained by one of the most careful and skilful manipulators of our time, in his successive small crucible operations, would seem to warrant the belief that some slight reduction of aluminium, and some action influencing the structure of the steel in the now well-established direction, had actually been brought about in these experiments. And although, as pointed out by Percy, neither Karsten nor Henry succeeded in discovering aluminium in specimens of Indian steel examined by them, both Mr. A. H. Allen of Sheffield and M. Osmond have stated that ordinary steel, made in an acid-lined furnace, not unfrequently contains a little aluminium, detected by processes believed to be perfectly accurate.

To return from this digression to the subject of the examination of the structure of steel: Dr. Sorby has shown in his interesting communications to our Society on the subject, that, in the attainment of trustworthy comparative results by this system, much depends upon uniformity of proceeding in the preparation of the surfaces for examination, so as to bring out the ultimate structure of the specimen and to avoid any interfering effects by accidental markings or scorings of the surfaces. The description given by Sorby of his careful microscopic examination, with high power, of varieties of steel subjected to different conditions of treatment, are most instructive; and, as pointed out by Roberts-Austen, they are in harmonious relation with the results of my investigations into the condition in which carbon exists in steel variously treated, and with Osmond's conclusions regarding the causes of the changes produced in steel by hardening, tempering, and annealing.

In the instructive discussion which followed the reading of Mr. Hadfield's valuable paper on aluminium-steel at New York last autumn, Professor Arnold of Sheffield also gave illustrations

of the value of a microscopic examination of the structure of steel in detecting the incipient fissuring or "pulling" of the metal, undetectable by the naked eye, and caused by the considerable linear contraction of a steel casting from which occluded gases are removed by the use of aluminium.

Dr. Wedding, in his valuable communication to the recent International Meeting at Pittsburgh on the "Progress of German Practice in the Metallurgy of Iron and Steel since 1876," states that the systematic application of Sorby's system of microscopic examination of prepared surfaces of steel and iron is continually extending at the German works, and that many series of experiments have demonstrated that by this system of examination characteristic features of grades of iron may be discovered, physical differences co-existing with identity of chemical composition explained, and evidences of the true grounds of disasters obtained.

Members of the Institute may possibly remember that, in a joint paper by Colonel Maitland and myself, communicated to them in 1886, on the causes of differences exhibited in the erosive action of the powder-gases upon the surfaces of steel gun-barrels, I showed that the development of structure of smooth surfaces of slices of the metal composing the barrels with which experiments were carried out, by the very slow solvent action which a chromic acid solution exercises, afforded valuable evidence, attainable by simple inspection, of the comparative amount of work or mechanical treatment to which the different steel forgings had been subjected, and which was demonstrated to affect very importantly the amount of resistance opposed by the surface of the gun's bore to the erosive effects of powder-gases. This method of examination, and the production of photographic records of the results, had however already been made use of by me, twenty-six years ago, at the time when the Government first entered upon experiments with projectiles of wrought iron and of steel, for use against armour-plates; and it may interest the members to see some photographs of small plates of metal, exhibiting the effect of the chromic solution referred to, which were attached to a report made by me to the Ordnance Committee in 1865—one of my many unpublished official reports of investigations made in connection with iron and steel in their applications to war-purposes. Considerable light was then thrown upon the

causes of difference in quality between different projectiles which closely resembled each other in composition, by the careful inspection of the structure, the distribution of the carbon, and other points brought to light by this method of examination. Before quitting this subject, I must refer to a very beautiful series of specimens of steel prepared by M. Osmond for examination by the microscope, some of which were represented by photographs at the recent Mining and Metallurgical Exhibition recently held at the Crystal Palace, and with respect to which we are to be favoured with a communication from him at this meeting. The specimens had been submitted to varied thermal and mechanical treatment, the temperatures to which they had been raised being accurately measured by means of the Le Chatelier pyrometer, which Osmond has used to such advantage in his previous investigations. The complicated character of the study of the structure exhibited by varieties of steel, wrought iron, and cast iron, is illustrated by M. Osmond's specimens, and must be obvious when it is remembered that the structure is a resultant not merely of the chemical composition of a specimen, but also of the conditions under which work has been done upon it, of the nature and extent of such work, and also of the molecular changes wrought in the specimen by the various conditions of temperature to which it may have been exposed. The study of this subject requires, therefore, to be vastly extended, and pursued under many varied conditions, if erroneous conclusions are to be avoided; at the same time, it is likely to prove an invaluable adjunct to the application of mechanical tests in the attainment of correct knowledge of the character of a specimen of iron or steel. These tests only afford information as to whether the material is capable of sustaining the desired strains, or to what extent it falls short of doing so. On the other hand, the appearance of a metal surface, examined with the aid of a developing agent and magnifying power, may afford information as to the actual structure of the metal; the character and distribution of the carbon; the presence or absence of slag; its freedom from cavities, or from pre-existing cavities which have been closed up by the working of the metal; the existence of characteristics due to exposure to a particular temperature and particular modes of treatment, and as to other points of importance bearing upon the value of the material for

the purpose to which it is to be applied. The system of examination of the structure of steel, with or without the aid of the microscope, appears destined, therefore, to be of great practical value to the metallurgist and the engineer, provided that the correctness of the conclusions to be drawn therefrom are carefully corroborated by the light of results of chemical examination and mechanical tests.

The report made by me in 1865, to which I just now referred, was preceded by a companion report dealing with occurrences which had, for the first time in our experience at Woolwich, arisen in connection with the then novel application of steel to the production of solid shot, namely, the development of cracks in stored projectiles, which, when received from the manufacturers, had appeared to be perfectly sound; and the occurrence, in one or two instances, of a sudden and somewhat violent rupture of the solid mass, attended by a sharp report. I need scarcely say that physicists and metallurgists had, at that date, long been familiar with the development of internal strains in masses of metal when submitted, while in a fused state or in a highly heated but still solid condition, to a treatment necessarily applied to the surfaces of the mass, and which therefore favoured the more or less sudden contraction and passage to rigidity of the superficial portions. As regards the applications of steel to the construction of projectiles, in which it was essential to secure a combination of considerable hardness with freedom from brittleness, the problems presented by this liability to the development of internal strains by the application of hardening or tempering processes were novel, and the subject presented difficulties which, at the present day, have not been altogether overcome, even in the case of projectiles. With respect to much heavier masses of steel, such as those presented by the several parts of our large built-up guns, the subject has taxed the powers of some of our most eminent scientific and practical authorities.

As regards the many varieties of projectiles which, twenty-six years ago, constituted experimental supplies made to the Government by several of our most eminent manufacturers, and which ranged in their nature from material scarcely presenting the characteristics of steel to high-carbon steel, the results of very careful

investigations of their composition, properties, and behaviour during storage, furnished much information which helped to determine the conditions to be prescribed in the supply of projectiles, and subsequently in their manufacture at Woolwich. The difficulties which had to be encountered by manufacturers in the production of *solid* projectiles on the molecular stability of which reliance could be placed, was illustrated by a statement made by an eminent firm, then already possessed of considerable experience in this special manufacture, to the effect that although they were then successful in tempering steel shot without difficulty, by cooling them uniformly both *externally* and *internally*, this result had been preceded by many failures. The successful manufacture, within the last five or six years, by Holtzer, the St. Chamond and Firminy Companies, and other French makers, of the hardened chrome-steel armour-piercing projectiles having only small cavities (without which their production would probably be practically impossible), is a remarkable illustration of the control which has been acquired, since the period of which I speak, over the treatment of steel, and especially of varieties, such as this chrome-steel, to which a very exceptional degree of hardness may be imparted without detriment to tenacity, by carefully elaborated processes of hardening and tempering. Experience in the application of these appears to have conquered, at any rate in very great measure, the originally considerable tendency to the retention of a state of unequal tension by the finished material for long periods, and the frequent yielding of the mass to the disruptive force thereby exerted. In visiting, in 1886, the several works at and near St. Etienne, where the chrome-steel projectiles were being produced, their successful manufacture being then of comparatively recent date, I saw, at more than one establishment, a large number of projectiles which had sustained spontaneous fracture. In one store where the finished shot were stacked, after the lapse of the period during which the tendency to the development of cracks or to rupture was stated to diminish gradually, I saw the head of one out of a pile of projectiles which had quite recently been projected to a distance of many feet by the violent spontaneous rupture of the metal. Instances of the development of flaws in these projectiles are now, so far as our experience at Woolwich goes, exceedingly rare, and the remark-

able power possessed by these formidable punching tools of penetrating 8 to 10 inches of armour without even sustaining any important alteration in dimensions, is a convincing proof of the uniformity of structure and mechanical stability of the highly dense and tenacious material of which they are composed.

The importance of *rest* in bringing about a diminution, if not the entire disappearance, of internal strains in masses of metal, is illustrated by the behaviour of these chrome-steel projectiles, which, at any rate in the earlier days of their manufacture, it was found necessary to store for several months before their transport to a distance could be ventured upon. My report of 1865 on this subject gives illustrations of the recognition, already at that period, of the effect of time in establishing chemical equilibrium in masses of metal. Thus, the United States Government had then recently instituted comparative experiments with iron guns newly cast, and with others produced at the same time, but preserved for lengthened periods, which demonstrated the importance of attention to this matter; and the object aimed at and attained by Rodman in his proposal to cast iron guns of large calibre upon a core instead of solid, and to cool the castings as rapidly as practicable from the interior, while retarding the cooling from the exterior, was to diminish the severity of internal strains set up in the cooling masses of metal, and to reduce the period of time required for the establishment of mechanical equilibrium in the castings. My old friend, the eminent chemist Thomas Graham, who was Master of the Mint when this subject was under examination by me, wrote me a very interesting letter in October 1865 on the subject of his experience of the tendency to the development of cracks in steel dies, and after mentioning that eight dies out of 200 which had been stored, after having been passed as thoroughly sound, had recently been rejected as having developed cracks, he stated that they had sound reason at the Mint for believing in one peculiarity of tempered steel dies, namely, that if kept in store for a year or two, they became less apt to crack *when in use*, and coined more pieces than dies newly tempered.

The possible existence of internal strains in masses of steel composing the tubes or barrels in which it may be said that the real life of a gun is centred (whether the external portions consist

of rings or of coiled wire) is obviously of vastly graver consequence, as affecting the stability of the gun, than the possible effect of a similar condition of things upon the efficiency of particular projectiles, and the importance of guarding against such a source of instability in the individual masses of which a gun is built up cannot be exaggerated. Since steel was first adopted as the material for the inner tubes or chases of our guns, some few casualties have occurred which careful investigation has shown it to be scarcely possible to ascribe to any other cause than the existence in the steel of severe internal stresses, which determined the rupture of the metal when it was subjected to the conflicting strains developed by the action of even very moderate powder-pressures. The condition in which the steel might have been, in such instances, when subjected to the action of the exploding powder-charge, may be illustrated by reference to the behaviour some years ago of the tube of a large gun, in which, after the third proof round was fired, a circumferential crack was found to have become developed in the front threads of the breech-screw. Upon removing the jacket from the tube, the crack extended forward along the chamber and into the rifling, and when the tube was placed in the lathe with a view of cutting off the injured portion, the crack suddenly developed itself with a loud report, and ran along to within eight feet of the muzzle; a spiral crack at the same time ran completely round the tube, which fell in two upon removal from the lathe.

The system introduced some years since of tempering, or oil-hardening as it is termed, the several parts of a steel gun, for the purpose of increasing the tenacity of the material, by raising the mass to a high temperature, and then immersing it in oil, has been demonstrated to result in the development of more or less severe internal stresses in the mass, which can only be removed by subsequent careful annealing; and until this latter practice was largely adopted, instances occurred from time to time at Woolwich, and at other gunmaking establishments, of the fracture of tubes and hoops of guns, either during their treatment in the workshop, or when at rest, or when, in the built-up condition, they have been for the first time exposed to the shock produced by the firing of the gun. One effect which the oil-hardening treatment has occasionally exercised in the case of particular

qualities of steel is that of developing minute fissures or cracks in the metal, either superficially or in the interior of the mass. This cannot, of course, be rectified by any annealing process, and it is still a question, to be determined by the teachings of experience and the results of investigations, whether any definite or reliable modifications in the composition of steel used for guns, tending to secure the desired combination of hardness and tenacity, may not be introduced, with the result that a method of treatment of the metal may be discarded which, however carefully applied, and however efficient the means adopted for reducing or neutralising its possible prejudicial influence upon the physical stability of the parts of which a gun is built up, carries with it some inherent elements of uncertainty and possible danger.

In referring to some of my early work connected with cast iron in its application to the production of ordnance, I have been much impressed by the extent of accord between conclusions arrived at in those days and the results of recent systematic and exhaustive investigations made by Mr. Thomas Turner, Mr. Keep, and others, into the influence of silicon and of other prominent impurities of cast iron upon its mechanical properties, and into the modifications in composition of the original pig iron, produced by repeated re-melting of the material in furnaces where it is not brought into direct contact with solid fuel. In a report of mine made after an official visit to various Continental gun-factories in 1855, I find statements given of the influence of silicon and of sulphur upon the condition of the carbon, the structure, the fluidity when melted and the mechanical properties of cast iron, based partly upon the results of personal observation and investigations, and partly upon information received at that time from experienced officials who directed those works, which statements, although some were then regarded with scepticism by my old friend Dr. Percy, are quite in accordance with the conclusions based by Mr. Turner upon his own experiments, and upon his careful examination, both of the results of Fairbairn's important experiments of 1853, on the effects of repeated re-melting upon the properties of cast iron, and also of the series of analytical

examinations and mechanical tests carried out by myself in conjunction with the late General Eardley Wilmot, then Superintendent of the Woolwich Gun Factories, in 1856–58, to which reference has already been made.

The valuable work of Gautier, Ledebur, and others, whereby the information acquired by Turner has been confirmed and extended, and the systematic investigation instituted by Jüngst for the German Iron Founders' Association on the utilisation of ferro-silicon for the improvement of castings, have combined to establish upon a sound footing the value, in connection with the treatment and application of cast iron, of that most amenable of all the constant associates of iron to the powers of control of the metallurgist. Jüngst's series of experiments seems to have clearly indicated the particular conditions under which silicon will contribute to the production of dense and homogeneous castings, and to have demonstrated that, with a judicious selection of the metal and even only a general knowledge of its composition, ferro-silicon may be readily applied to the attainment of very advantageous results.

The remarkable regularity of structure, and great uniformity, of successive products of the re-melting of pig iron attained at the period to which I have referred, at the chief Continental gun-factories, especially at those of Trubia and Liége, were due to the bestowal of great care on the selection and uniform treatment of the metal employed, and to a thorough practical acquaintance with the effects of repeated re-melting, of mixing pig iron of different characters, and of the addition of small doses of ore, and especially of small proportions of a sulphide, to the re-melted metal, in facilitating the production of the close-grained, regularly and finely mottled iron, of very uniform character and of high tenacity, which long experience had shown to furnish artillery of the greatest powers of endurance.

I have referred with some interest to a report presented to the War Department by General Eardley Wilmot and myself in 1856, upon a visit of inspection paid that year to the Silesian ironworks at Gleiwitz and Königshütte, for the special purpose of seeing Eck's gas reverberatory refining furnace in operation, with a view to its probable adoption at Woolwich for the production, by a partial refining process, of the particular variety of iron which

experiments had shown to be suitable for guns. The pig iron produced at those works was highly silicious; a sample of the metal which we saw submitted to the refining treatment in that furnace contained 4·66 per cent. of silicon, 2·06 per cent. of carbon, phosphorus, 0·56 per cent., and sulphur, 0·04 per cent. The product of its treatment in the gas-furnace, which lasted about five hours after fusion of the metal, contained 0·62 per cent. of silicon, the proportions of phosphorus and sulphur remaining practically unchanged. In referring to this result in our report, made thirty-five years ago, we say, "It is not surprising that the very efficient method of refining at Königshütte does not do more towards the removal of the other impurities, phosphorus and sulphur, since it has been shown that they are not abstracted from the iron even by the treatment proposed by Bessemer, and that the puddling process is, therefore, as yet the only mode of treatment by which the very persistent compounds of those elements with iron can be made to undergo decomposition." With reference to this extract, it is interesting to find Dr. Herman Wedding, in his valuable communication to the recent Pittsburgh meeting, already referred to, make the following statement with reference to malleable iron:—"Puddling, which, after the invention of the Bessemer process, and still more after the introduction of the Thomas process, was supposed to be rapidly approaching its extinction, has been in Germany not only maintained, but in some respects extended and improved. True, puddled iron relatively retreats year by year before the advance of ingot iron, but the change is a slow one."

In Dr. Wedding's remarks on the production of malleable iron (or *weld iron*, as he aptly calls it), which is still furnished exclusively by puddling in Germany, he goes on to say that the essential improvements in puddling have not been accomplished either by the mechanical revolver or the rotatory furnace, but by the more perfect utilisation of the fuel by means of gas-firing and double furnaces. Further on in his paper, Dr. Wedding dwells, however, upon the revolution which the modification of the Bessemer process by Thomas and Gilchrist has already brought about in Germany, to whose metallurgists we owe the first successful practical development of the basic treatment, and who are still much the largest producers of steel by this process, having also been the first to

apply to fertilising purposes the slag, rich in phosphate of lime, which, instead of remaining a refuse product difficult of utilisation, now finds a ready sale in a simply ground condition; over 600,000 tons having been thus utilised during last year. Of the 2,600,000 tons of basic steel which were made in 1890, nearly 1,500,000 tons were produced in Germany, against 503,000 tons in England and 240,000 in France.

The details which Dr. Wedding gives of the operation of the basic Bessemer process at Hörde and other German establishments, and of the extent to which its development has already attained at several of the largest works, are very interesting. The necessity, in Upper Silesia and at establishments in other parts of Germany, for the addition of phosphorus, either in the form of the phosphoric slag or of phosphorite, for the production of pig iron sufficiently rich in that impurity to be thoroughly suitable for treatment in the converter, is in remarkable contrast to the difficulty presented in the treatment of the Silesian pig in the Eck-furnace, by its contamination with a somewhat high percentage of phosphorus, as pointed out by me thirty-five years back.

The data already supplied by the examination of test-samples of metal, slag, and gas taken at different periods in the course of the complete operation of the basic process, have afforded indications of the occurrence, during the brief duration of the treatment (fourteen to fifteen minutes), of a complicated series of reactions; and much light has evidently still to be thrown, by systematic research, upon the conditions which have to be fulfilled to ensure the practical attainment of uniformity in the operation. I may just note, among the many points of interest and matters for further investigation referred to by Dr. Wedding, the return, during the dephosphorisation, of some of the manganese which has passed out of the metal in the first part of the operation, and the elimination by it of sulphur; the volatilisation of sulphur, and especially of phosphorus, sometimes to a very considerable extent, during the treatment, and the consequent variation in the composition of the slag (especially with variations of the temperature), although the original proportions of phosphorus and lime are the same in different operations. All attempts to accomplish the regular production of a high-carbon ingot steel by the basic Bessemer process appear to have failed hitherto in Germany; and,

indeed, I see it stated upon apparently a very competent German authority, that complete decarbonisation of the metal is necessary in the process before dephosphorisation can take place.

The analytical results given by Dr. Wedding of a series of samples taken from the Bessemer converter during the successive stages of a basic operation, show that when the percentage of carbon had been reduced from its original amount (3·60) to 1·33 per cent., or by 63 per cent., and the silicon from 0·58 to 0·07 per cent., or by 88 per cent., the phosphorus had become reduced only by 18 per cent. of the original amount (from 2·75 to 2·25); that when 80 per cent. of the total carbon had been removed, about 41 per cent. of the phosphorus had been abstracted; and that when this impurity had been reduced to 0·06 per cent. at the termination of the blow, there was only 0·105 per cent. of carbon in the product.

On the other hand, in an interesting discussion evoked by an important paper on the manufacture of basic *open-hearth* steel, recently communicated by Mr. James Davis of Rotherham to the Cleveland Institution of Engineers, it was stated by Mr. William Galbraith that if the phosphorus in the metal is somewhat low (1·5 per cent.), and the carbon relatively high (3·5 per cent.), it is quite an easy matter so to work the charge that it is dephosphorised, while a considerable percentage of carbon is left in the metal. Mr. Davis stated, moreover, as the result of his experience, that the phosphorus must be eliminated in the presence of carbon, and that if the phosphorus is not all gone when the carbon has disappeared, it is necessary to add *fresh carbon* in the form of low-silicon hæmatite pig as long as there is any phosphorus to remove.

In Mr. Sandberg's paper on steel rails "chemically and mechanically considered," communicated last year to the Institute of Mechanical Engineers, the addition of silicious hæmatite iron during the carrying out of the dephosphorisation (and before the manganese is added), which is referred to as a valuable suggestion due to Mr. Windsor Richards, conducing to the success of the process, is stated, on the other hand, to have the effect, *through the intervention of the silicon*, of preventing rephosphorisation of the steel.

Mr. Percy Gilchrist observed, in the discussion on Mr. Davis's

paper, that if steel is to be made by the open-hearth basic process, containing 0·05 per cent. of phosphorus and carbon up to about 0·5 per cent., it is quite indifferent to the skilful maker whether he starts with a material in the bath containing 2 per cent. or 0·1 per cent. of phosphorus.

The difference in the conditions under which the basic process appears to operate in the open-hearth and in the converter, and the diversity of views entertained by different workers, as indicated by the foregoing, afford very interesting illustrations of the multiplicity and complexity of the chemical problems which present themselves to the metallurgist in grappling with the application of a new process, in conjunction with different methods of treatment.

Dr. Wedding's observations on the absolute dependence of the development of new metallurgic processes, like that under discussion, upon the results of the labours of the analyst, the chemical investigator, the physicist, and the microscopist, and his illustrations of the thoroughness with which this all-important fact is appreciated by the German metallurgic establishments, afford new occasion for a regretful recognition of the distance which we are still behind our Continental brethren in availing ourselves of the advantages afforded by the constant pursuit of scientific research, and the thoroughly efficient, systematic, and direct application of the labours of the scientific investigator to the daily operations at works of all kinds, although it must be acknowledged that of late years we have made important progress in these directions. It has certainly been humiliating to have to admit that industries which the genius of individual Englishmen, possessed of exceptional powers of applying to important practical purposes the results of research, have created and have developed to an extent foreshadowing their high importance, gradually passed out of our hands through the far-sightedness of the Germans, who have very long since recognised the absolute dependence of progress in such industries upon the constant pursuit of chemical research into the far-reaching and continually spreading ramifications of organic chemistry. Thus, in fields of work where, in days past, and even of late, our industrial chemists have been content to pursue their attempts at progress with the co-operation of one or two young chemical assistants, small armies of highly-trained chemists, who have gained academic honours, and have won their spurs in original

investigation, are in constant employment at the magnificent manufacturing establishments in Germany, systematically pursuing researches which constitute successive indispensable links in a great net-work of exhaustive inquiry, and which, while conferring large benefits upon the science itself, are continuously productive of improvements in existing processes, or of the development of new methods, while, ever and anon, they result in some fresh discovery of great technical importance and high commercial value. Similarly elaborate and comprehensive arrangements now exist at important German iron and steel works for systematic investigation and comparison of materials, of products and processes. Wedding remarks most cogently that the combined operations of chemistry, physics, and mechanics have furnished, and are continually preparing, the foundations for important advances in the industries of iron and steel. Even when, through some subtle inspiration, a process was revealed to us, destined to revolutionise those industries, the inspiration would for the time have been barren of result, but for the mechanical knowledge and constructive genius of him to whom we owe its practical realisation, concurrently with the inspiration; but even he will gratefully acknowledge that the systematic application of chemical research has been indispensable to the crowning of his work, for no one has more emphatically recognised the intimate connection of chemical research with the advancement of the iron and steel industries than Sir Henry Bessemer. In the most suggestive address delivered by him as our President in 1872, he said that, "in dealing with the differences in the quality of iron from different ores, the rule of thumb had given way before the proofs of chemistry. The iron manufacturer no longer believed in some occult difference in the nature of the iron he treats, but his well-ordered laboratory furnished him daily with the quantity and quality of the deleterious matters which his raw material contains; and" . . . "although certain of these still make a determined stand, it is no small point gained that we know the number and nature of the enemies we have to struggle with."

At the risk of wearying you, I have one or two more observations to offer bearing upon the further development of the basic process.

In connection with the attainment of uniformity in the working of this process, expectation seems to be entertained in Germany of the importance of the Darby method of recarbonising the decarbonised and purified metal, of which a description was given by Herr von Thielen at the Pittsburgh meeting last October, and which consists in filtering the molten purified metal through a column of carbon fragments, or in allowing a stream of particles of carbonaceous material to come into contact for a more or less prolonged period, or to a more or less complete extent, with the liquid metal. The experience with this process at the Phœnix Works near Ruhrort, on the Rhine, is stated to have demonstrated that the recarbonisation of basic converter steel to the desired extent is readily accomplished, and since it is carried out in the almost complete absence of the phosphoric slag produced in the converter, no important rephosphorisation of the metal takes place during the operation. Its application in connection with the open-hearth process is also stated to have been found advantageous, and, with the Bessemer process proper (or acid process), the experience at the Phœnix Works is said to have shown that any required carbonisation can be accomplished by the Darby method with greater safety to the quality of the product than by the use of spiegel or of ferro-manganese, with greater economy, and without the increase in the proportion of manganese in the ultimate product which the employment of these necessitates. It remains to be demonstrated how far the results of practical experience in the hands of others will confirm the conclusions which Mr. von Thielen's statements appear to warrant; and it must not be forgotten that functions are exercised by manganese in the employment of its compounds as an adjunct to the Bessemer process, which are distinct from that of its being the medium for furnishing a very effective recarbonising material. It is impossible to touch upon this subject without regretful and sympathetic reference to the loss which the metallurgical world has sustained in the death, at an advanced age, of Robert Mushet, who followed his father's footsteps in making iron and steel fruitful subjects of study, and whose name must ever be gratefully associated with the revolution which the Bessemer process accomplished in their applications.

Most unfortunately for myself, I was prevented by numerous official duties from attending the meeting of the Institute in New York last autumn, but, in following with keen interest the press accounts as they reached us of the proceedings at that meeting, I observed with much satisfaction that while they were rich in valuable communications and discussions relating to steel, and to investigations of especial importance to the steel-maker, the place of honour was assigned to the subject which constitutes the starting-point of all our work—the production of pig iron. The interest, and, I may say, astonishment excited by the facts brought before the meeting in Mr. Gayley's paper on the development of American blast furnaces, with especial reference to large yields, were reflected in the important observations which the paper elicited from our eminent ex-President, Sir Lowthian Bell, whose classical investigations connected with the blast furnace were so justly referred to by Mr. Gayley as having lifted the manufacture of pig iron out of the rut of a rule-of-thumb practice, and placed it upon a thoroughly substantial, scientific basis. The discussion upon Mr. Gayley's paper, and the circumstance that this discussion occurred on the occasion when our members were the much-honoured guests of our blood-allies, our most formidable and most friendly rivals, an occasion which will ever constitute one of the most memorable incidents in the history of our Society, afforded striking illustrations of the invaluable services rendered to all who are practically interested in the industries of iron and steel throughout the world, by those who, in initiating the organisation of this Institution, were successful in securing a general recognition of the inestimable benefits to be derived from the free interchange of knowledge, and of the results of individual experience, from the candid discussion of successes, failures, and diversities of views and practice, and from the combination of friendly rivalry with hearty co-operation which now pervades, and promotes success in, the work of those who devote themselves to the advancement of the science and practice of these great industries.

The formidable difficulties which had to be overcome in securing the uniform attainment of the results essential to the production of durable cast iron ordnance were just realised at the Woolwich

Foundry, and in course of being thoroughly conquered, when the Armstrong system of rifled breech-loading guns, and Lord Armstrong's method of construction of guns from welded coils of wrought iron, gave the death-blow to cast iron in 1859, but only to give place in its turn, although gradually, to the adoption of steel as a material for ordnance.

The practical difficulties in the way of securing uniformity in strength and durability in guns even of small calibres, produced from crucible steel cast in one single mass, had been demonstrated by the uncertainty of the powers of endurance of guns produced by this method upon the Continent, long before the employment of steel ordnance was contemplated in England. The subsequent gradual introduction of steel for gun-construction in our service, in conjunction with wrought iron, afforded experience in regard to certain methods of building up guns, and also with respect to the character of steel suitable as a material for guns, which was of considerable service in facilitating the adoption of definite conclusions on the subject of the use of steel alone as the material for guns of all calibres.

In August 1882, it was decided by the Government Committee which had been intrusted with the inquiry into the course to be pursued in the future construction of ordnance, to recommend that the use of wrought iron in gun-manufacture should be altogether abandoned, and a specification of tests was prepared to govern the character and quality of steel to be employed in the construction of ordnance. Shortly afterwards, recommendations were made respecting the methods to be followed in the production of the different parts of which a steel gun was to be built up, and the treatment which they were to receive, and a strong opinion in favour of the employment of open-hearth steel to the exclusion of crucible steel was expressed, in view of the importance of uniformity in the material used. It was to be expected that, as practical experience in the manufacture and employment of steel guns accumulated, and as the conditions to be fulfilled by a thoroughly suitable material, and the nature and causes of the difficulties connected with its production and treatment, became better known, the specification of tests to be applied, and of the treatment which the masses of steel to be tested were to receive, would have to undergo modifi-

cations from time to time; and by no means insignificant have been the problems involved in a satisfactory settlement and definition of qualities, the fulfilment of which might be expected to constitute a guarantee of the fitness of the particular portion under examination of the future structure to fulfil its functions as an integral part of the gun, without exacting conditions unnecessarily onerous. Much important information has been acquired in the course of the application of tests to steel-supplies of different makers; information which has contributed directly to the improvement of the material used in the construction of guns and to its treatment. No attempt has hitherto been made to introduce into the specifications governing the supply of steel for this service any numbers defining, even within wide limits, the *chemical* composition of steel to be employed, *i.e.*, to prescribe limits of variation in the proportion of carbon, or the maximum permissible amounts of the chief foreign ingredients which occur in steel. Although great light has been thrown, by the joint labours of chemists, physicists, and metallurgists, upon the influence exerted by small proportions of various elementary bodies upon the properties of pure, or nearly pure, iron or steel, our knowledge does not as yet extend to the attainment of sufficiently definite information respecting the modifying effects of variations of the proportions in which different constituents *co*-exist in the metal, or of the superaddition of some small proportion of what may be termed an abnormal or exceptional component, to warrant the chemist in attempting to define with sufficient confidence a particular chemical composition, or a series of alternative compositions, of steel, the conformity with which, or with one of which, should afford a guarantee, or even a sufficiently trustworthy indication, of the fitness of the material for gun-manufacture.

This subject embraces so many considerations of interest to the steel-maker, and so many topics upon which an interchange of views cannot but be valuable, that I feel sure of the favourable reception which will be given to, and of the instructive nature of the discussion which will be elicited by, the communication thereon which has been promised us by a most competent authority, Dr. W. Anderson, the Director-General of the War Department factories.

It would be difficult to find a parallel, at any rate outside the realms of organic chemistry, to the extent and variety of chemical and physical research to which the study of the nature, production, and properties of steel has given rise, and to the number of interesting and more or less complex problems which have presented themselves in the course of investigations of this class. The remarkable operation and result of the old cementation process, and the effect of the assimilation of even a very small proportion of carbon in imparting to iron new characters, as distinct from those of the pure metal or of cast iron, as though indeed it were a different metal, have naturally led many eminent chemists, from an early period in the history of steel up to within a recent date, to search for other points of chemical difference between iron and steel, and to devote much elaborate experimental research to the endeavour to trace the cause of the characteristics of steel to the influence exerted by minute quantities of other elementary bodies, or of compounds thereof, in this material. Thus, the observations of Berthollet, of Thénard, of Savart, and of Depretz regarding the effects of heating iron in ammonia gas, and of an increase in weight thus sustained by the metal, led to the detection and estimation of nitrogen in iron and steel by Schafhäutl and Marchand, and to subsequent investigations of the effects of heating iron in ammonia and in pure dry nitrogen by Buff and by Frémy, of whom the latter, about thirty years ago, carried on for a time a lively controversy with Caron on the part played by nitrogen as a constituent of steel. Bouis and Boussingault both devoted much labour to the examination of cast iron, malleable iron, and steel for nitrogen. In nitrogenised iron, obtained by heating iron in ammonia, whereby its specific gravity is slightly reduced, as much as 2·6 per cent. of nitrogen was found; and, excepting in one case of pure iron prepared in the wet way, nitrogen in estimable proportions was found in all samples of iron and steel examined, including samples of Krupp's steel; but no definite conclusions could be drawn, from the results obtained, as to any part taken by nitrogen in determining or modifying the properties of steel, and it could only be stated that iron, in combining with nitrogen, acquired distinct qualities, which, however, are not those characteristic of steel. In his most suggestive address, delivered to us in this hall in 1885, Percy

gave it, however, as his decided opinion that the "nitrogen iron and steel" question should not be regarded as finally disposed of, and pointed to the fact that no satisfactory response had been yet given to such questions as why, in case-hardening iron, animal matters, or certain other substances rich in nitrogen, should always be employed, and whether any nitrogen or compound of nitrogen is imparted to the case-hardened portion of iron. Doubtless this interesting subject is destined at some future time to receive fresh study at the hands of one or other of those among our own body who have by their systematic investigations contributed so importantly of late to our knowledge of the relations of several other elementary bodies to iron.

The study of the state in which carbon exists in steel; the influence exerted upon its condition or distribution by the submission of steel to those methods of treatment which develop the remarkable modifications that it is capable of assuming and sustaining in its physical character; the cause of the succession of colours which the surface of the material acquires by the formation of films of transparent oxide of various thicknesses, as it passes through successive stages of hardening or tempering, and many other points of interest relating to carbon in steel, have been made subjects of elaborate chemical research since the days of Karsten to the present time, and it is in these directions that I also have endeavoured to contribute a little to the accumulation of definite results which are gradually tending to secure to the metallurgist the power to control the qualities of his products, so as to enable him to secure in steel, made for any special purpose, the essential characteristics. And it is here that the physical sciences, which, since the days of Davy's discovery of the alkali-metals through the agency of electrolysis, have continued in rapidly increasing degree to co-operate intimately with chemical science in revealing Nature's secrets, have most importantly contributed, within the last few years, to our attainment of a clear understanding of the reasons for the changes which steel undergoes in its physical properties, and therefore of the conditions which determine those changes.

The instructive and philosophical paper with which M. Osmond favoured the Institute a year ago, and the intimate

relations which the results there detailed bear to those of purely chemical investigations, such as those in which I engaged a few years ago, with Mr. Deering's co-operation, at the instigation of the Research Committee of the Institution of Mechanical Engineers, afford an excellent illustration of this close union between the results of work which the physicist and the chemist severally accomplish. Osmond's study, by means of the Le Chatelier pyrometer, of the phenomena observed during the slow cooling of iron, steel, and white pig iron, led him to very definite and apparently well-founded conclusions on the relation between the condition of the carbon in the metal and the phenomena of recalescence, the study of which we owe to Professor Barrett; and we have been much indebted to our Member of Council, Professor Roberts-Austen, for having placed clearly before us the views which Osmond has based upon the results of his interesting experiments. The progression in research and reasoning which led up step by step from the starting-point of the illustrious Joule's work in 1850, through the observations of Chernoff and of Gore, the work of Barrett and of Wrightson, Barus and Strouhal, Pionchon and Le Chatelier, to the crowning researches of Osmond, and the definite establishment of the existence of two allotropic forms of iron, were placed before the scientific public with admirable clearness by Roberts-Austen in his lecture to the British Association in 1889, which was so usefully supplemented by Osmond's last paper.

Among other interesting conclusions based upon the results given by Osmond, he is led to consider that, as the extent of change of one allotropic form of the metal to the other is regulated by the rapidity of cooling, and as the predominance of one over the other influences the degree of hardness of the material, explanation is thereby afforded of the hardening of steel, at any rate to some important extent, independently of the carbon which it contains, and this view he supports by reference to the fact that electrolytic iron may be hardened by very sudden cooling. It is true that the specimen of this form of iron used in Osmond's experiments was found to contain 0·08 per cent. of carbon; but this would not militate against the view which he adopts, that the influence of carbon is of the same character as that of the rate of cooling upon the iron, both combining to produce the final result. That is to

say, during the process of tempering, the β modification, or the form in which the iron exists when highly heated (in which form the molecules have been retained or fixed by the process of sudden or very rapid cooling), passes over into the a or normal, soft, condition of the metal *pari passu* with the transformation of the so-called hardening, or free, dissolved carbon into cement- or combined carbon; *i.e.*, the particular iron-carbide in which form the carbon was shown by me to exist entirely in thoroughly annealed steel, and which had some time previously been isolated by Dr. Müller from Bessemer steel.

The interesting results which Osmond obtained by extending his thermal researches to the investigation of the influence of foreign elements upon the critical points of iron and steel appeared to establish the soundness of Professor Roberts-Austen's suggestion, made in 1889, that the nature of the influence exerted upon iron by the association with it of small proportions of other elements is in accordance with the periodic law, and that the effect of a given element in retarding or promoting the passage of ordinary iron to an allotropic condition might perhaps prove to be the direction in which the connection of those influences with that law would be made manifest. Osmond's results certainly appear to demonstrate that the elements whose atomic volumes are less than that of iron, tend by their association with it in small proportions to exert a hardening effect, or to delay the change of β into a iron during the cooling of the material, while an inverse influence is exerted by elements having higher atomic volumes than iron, their association with it exerting therefore a softening influence, like that of annealing, by promoting the change of the allotropic to the normal form of the metal.

The effect of some of the latter elements in increasing the tensile strength and hardness of the metal is ascribed by Osmond to the influence exercised by their individual properties, or by the properties of their alloys with the metal,—an influence distinct from the function just referred to, and corresponding to the influence of the β or allotropic iron in ordinary carbon-steel.

While we must thoroughly recognise the great interest and value of the researches to which M. Osmond has so successfully devoted himself, one cannot but feel that the extreme difficulty

of tracing to their origin, and eliminating, conflicting effects and erroneous results due to the presence in the metal of even very small quantities of elements other than those the effects of which it is desired to establish, renders great caution necessary in drawing broad conclusions, and enhances the importance of obtaining indications of the legitimacy of such conclusions by the pursuit of other quite distinct lines of research. Hence M. Osmond's reference to results obtained by him in the study of the influence which different foreign elements exert upon the magnetic properties of iron, possesses special interest and encourages the hope that a pursuit of work in this direction may contribute valuably towards the confirmation of the conclusions based upon his thermal results.

The difficulty of obtaining supplies of really pure metals to serve as the basis for researches upon the distinct influence of individual impurities, or frequently associated elements, upon the properties of metals, has recently been experienced by the Research-Committee of the Institution of Mechanical Engineers, in their endeavours to supply proper material to Professor Roberts-Austen for the investigation which he has undertaken to conduct "on the effects of small admixtures of certain elements on the mechanical and physical properties of iron, copper, and lead," and which, from the particular line of investigation commenced by him, will, it is hoped, furnish important results. The methods which he has devised and elaborated for recording automatically the successive indications furnished by the Le Chatelier pyrometer must prove of great value, not merely in connection with the particular researches upon which he is entering; and I am glad to know that the members will at the present meeting be furnished with a description of these methods. The fact that, for the reason just now given, Roberts-Austen felt compelled to select gold as the basis of his initial experiments, serves to remind us how intimately the study of any one particular metal is connected with researches on the properties of other metals, and recalls to mind the suggestion which has been more than once made in the life of the Iron and Steel Institute, especially in recent years, that members may live to see its sphere of activity so greatly enlarged by the diversity of channels into which researches on the relation of iron and steel to other metals rapidly spreads, that new branches

of metallurgical work will have gradually become most intimately interwoven with our original themes of study; the result being a steadily progressive expansion of the functions of our Society, until they embrace the cultivation of all the most important branches of metallurgy, so that the title of this Institution may in good time fitly become transformed into that of "The Metallurgic Institute of Great Britain."

In the discussion which followed the reading of Mr. Keep's interesting paper communicated to us a year ago, upon aluminium in carbonised iron, Sir Lowthian Bell referred to interesting observations, having an important bearing upon the effects of the addition of aluminium to iron and steel, which were made by him at the time when, as the first manufacturer of aluminium in this country, he was studying the phenomena and results attending the production of alloys of that metal with copper. On the same occasion, the views expressed, by more than one who took part in that discussion, upon the probability that the recorded effects of the addition of aluminium to iron or steel in increasing the fluidity of the molten metal might be ascribable to its action as a deoxidising agent, or a reducer of the oxide of iron contained in the melted mass, recalled to mind the observations made by me in 1864, and subsequently, upon effects of certain other elements upon copper and some of its alloys in the preparation of castings.

The reason of the practice which was followed many years ago, of adding small quantities of lead to brass, or to the copper-and tin-alloy termed gun-metal, in order to promote the production of sound castings, was traced to the deoxidising effect exerted by that metal upon the cuprous oxide always existing in more or less considerable proportion distributed through the copper or its alloy; and the important improvements effected in the working properties of copper by the introduction of phosphorus in small proportion into the fused metal, or by employing a small amount of phosphide of copper, or of copper, combined as it readily can be with about 4 per cent. of phosphorus, were shown to be due, not to any appreciable retention of phosphorus in the composition of the metal, but to the abstraction of oxygen from it. This application of small proportions of phosphorus was resorted to already in 1849 by Mr. Parkes, of Birmingham, for the improve-

ment of brass- and copper- castings for printing and embossing rollers, &c. In 1854 the French Government employed phosphorised bronze experimentally as a material for ordnance; the results of researches by myself on the combinations of phosphorus with copper and on phosphorised copper, were published in 1865, and the subject was taken up in 1870 by the Belgian Government at the instance of Montefiori-Levy and Künzel. Guns of phosphorised bronze were manufactured and tried, when it was demonstrated that, while the employment of small quantities of phosphorus operated very beneficially in facilitating the production of sound castings, through its deoxidising action, and in promoting uniformity of structure, the retention of even a minute proportion of phosphorus by the alloy operated prejudicially upon the strength of the material.

In 1883 so-called "*silicium copper*," produced by the addition of a somewhat rich copper-silicon alloy to melted copper, was publicly vaunted as an especially excellent material for telephone wires of small diameter, on account of its combining great tenacity with high electrical conductivity. Analysis of the wire revealed the absence therein of any but occasional traces of silicon, and it owed its qualities unquestionably to the deoxidising action of the added silicon.

The investigations of Turner, Hadfield, Keep, and others on the influence of silicon on the properties of iron and steel have shown that the employment of small proportions of ferro-silicon, which was found many years ago by Sir Henry Bessemer to produce sound steel castings, exerts at any rate one action, that of deoxidation, quite analogous to that of silicon-copper when added to copper and its alloys; and, at the discussion which followed upon Hadfield's exhaustive paper, read at New York, upon aluminium-steel, the general opinion appeared to be, except perhaps in the case of Professor Arnold, in favour of the conclusion that the effects of aluminium and silicon are strictly analogous in two directions at least, viz., in promoting the production of sound castings by the exertion of a deoxidising action, both upon iron-oxide and upon carbonic oxide which are dissolved in the fluid metal, and also in the elimination of carbon in the graphitic form from white iron.

Metallurgists are greatly indebted to Mr. Hadfield for the very

important contributions which his systematic researches have made to our knowledge of the relations of manganese to iron, and of which he gave us so interesting an account at Glasgow three years ago; he has much increased our obligations by his history of the alloys of iron and silicon, communicated to us in Paris in 1889, and by his comprehensive and valuable treatise of last autumn on aluminium-steel, to which I have just referred. From the careful sketch on the development of the aluminium industry with which he prefaced his paper, it appears that the cost of this metal has become reduced to a figure for which, even after the successful development of the Castner and Netto processes, and the promise afforded by the elaboration of the Cowles process, we were not prepared; and that, both by the direct electrolytic method and through the agency of sodium, also produced electrolytically, the metal can now be supplied to the market at under 6s. per pound. Vastly as the technical application of aluminium has been advanced by the remarkable progress made of late in its manufacture, it is evident that if, as appears to be beyond doubt, the important function of aluminium, when added in small quantities to iron and steel, is practically the same as that exercised by silicon, its employment, or even the use of ferro-aluminium, the cheaper and equally suitable alloy, cannot compete in point of economy with the use of ferro-silicon, even if the former be, as has been maintained by some, decidedly more energetic in its action than silicon. In referring to what appears to be an accepted conclusion, that the addition of about 0·10 to 0·15 per cent. of aluminium to steel or iron is the minimum requisite for attaining the advantages to be derived from its use, Hadfield shows that this addition would entail an increase of from 18s. to 27s. per ton in the cost of the metal, while even if as much as 0·5 per cent. of silicon, in the form of ferro-silicon, were required to produce corresponding effects, the resulting addition to the cost of the metal would be only about 4s. 6d. per ton. Unless, therefore, it be established that some important distinctive function may be exercised by aluminium, when alloyed in appreciable quantities with iron, quite apart from its deoxidising effect, no advantage would appear to result which could compensate for the great addition to the cost of the metal caused by the employment of

even small quantities of aluminium, at its present comparatively low price.

Hadfield, with the important co-operation of Osmond, has disposed of the assumption, which found favour for some considerable time, that the addition of aluminium has the effect of lowering the melting-point of steel, while, on the other hand, his experiments appear to confirm previous observations that heat is developed by an intimate union of aluminium with steel, just as was observed by Sir Lowthian Bell to be the case when it is alloyed with copper.

Although a somewhat higher proportion of aluminium than of silicon may exist in aluminium-steel without imparting brittleness to the material, the region of brittleness appears to be reached when less than 1 per cent. of aluminium is present, although, as in the case of silicon-steel, its malleability is not destroyed until over 5 per cent. has been added, and it is very noteworthy that aluminium does not at all share the remarkable properties of manganese, discovered by Hadfield, that, by a further increase in the proportion above that required to produce brittleness, the property of increasing toughness and strength re-asserts itself. Moreover, the addition of aluminium to iron does not, as with manganese, interfere with its magnetic susceptibility. The tendency of aluminium to increase by its presence the crystalline structure of the fused steel has already been referred to, and the similarity, in this and some points relating to the influence upon mechanical properties, between aluminium and silicon, appear well brought out by Hadfield's experiments. On the other hand, it appears that the tensile strength of iron is not increased so much by aluminium as it is by silicon, and that the statements which have been made as to a considerable increase being effected in the elastic limit of the metal by small percentages of aluminium have, like those regarding the supposed reduction effected in the melting-point of steel, been based upon erroneous observations.

In Mr. Sandberg's valuable paper on "Steel Rails," to which I have had occasion to allude, he showed that the addition of as much as 0·3 per cent. of silicon to steel, containing 0·3 to 0·4 per cent. of carbon, did not harden the metal nor render it brittle, and that the addition of 0·2 to 0·3 per cent. greatly facilitated

the casting of steel and secured soundness; but that with the employment of that proportion difficulties arise, due to great shrinkage of the metal, so that, unless only small ingots are cast, it is not advisable to employ more than 0·1 per cent. of silicon; and in this statement he was confirmed by Mr. Windsor Richards.

Before leaving this most attractive subject of the relation of silicon and aluminium to iron, I must refer incidentally to a property of aluminium of considerable interest and probable value which was pointed out to us in the course of a discussion at our meeting a year ago by Mr. James Riley, who has done so much sterling work in connection with the alloys of iron and steel; namely, that it has the power of inducing or promoting intimate union or thorough alloying, which otherwise was not readily accomplished, between steel and certain other metals, such as copper and nickel.

The results of the experiments of Hadfield and others, to some few of which I have ventured to refer, certainly rank in interest and importance with, although in some respects they may not be so remarkable as, those which we owe to Hadfield regarding the various alloys of manganese and iron, and we may congratulate all interested in the further development of iron- and steel-manufacture on the valuable progress which has been made during the past twelve months in our acquaintance with the relations of aluminium to iron and steel through the work of able investigators, especially in England, France, and the United States, who have at hand the resources necessary, and are thoroughly competent, to combine scientific research with exhaustive experiment upon a practical scale. Our much-lamented President of 1885, than whom no one has more usefully contributed to advance our scientific knowledge of the results of association of different elementary bodies with iron, pointed with prophetic significance in his inauguratory address to the fact, that much yet remained for careful investigation concerning the alloys of iron. The Mitis castings were then just attracting attention; the chromium alloys were referred to by Percy as having of late excited considerable interest, and they were commended by him to iron- and steel-makers as well worthy of consideration. Since then, this branch of study has indeed been

actively pursued in directions scarcely dreamt of by him, and the practical aspect of the work which is being accomplished cannot be better illustrated than by reference to the results obtained by James Riley, J. F. Hall, and others, in investigating the properties and developing the applications of nickel-steel. I have already had occasion to refer to the interesting experiments made by Faraday and Stodart, about seventy years ago, on alloys of steel made "with a view to its improvement;" prominent among these were alloys of nickel, which they prepared by alloying "good iron" (horse-shoe nails) with proportions of nickel ranging from 3 to 10 per cent., having been led to these experiments by an examination of the composition of meteoric iron, to which a very high degree of malleability was ascribed. They observed that the products containing the smaller percentage of nickel appeared equal in malleability to pure iron, and that the combination of nickel with iron had a tendency to prevent rust by exposure; on the other hand, they state that when steel was alloyed with nickel in the same proportion, the latter appeared to accelerate the oxidation of the metal by exposure, an observation which, curiously, is quite at variance with that of Mr. J. Riley, who laid stress, in his paper of 1889, upon the practically non-corrodible character of steel rich in nickel. The general effect of nickel, alloyed with mild steel in proportions of from 2 to nearly 5 per cent., in raising the elastic limit and breaking strain of the metal, appeared clearly demonstrated by Riley's experiments, and the interesting facts were established that while the characteristic hardness was intensified as the proportion of nickel was raised to 20 per cent., additions beyond that amount tended to make the steel softer and more ductile, and to neutralise the effects of high proportions of carbon. In this respect, therefore, nickel appeared to behave in a manner corresponding to the peculiar behaviour of manganese as first established by Hadfield. The valuable effects produced by the use of nickel, as set forth in Mr. Riley's interesting paper, were fully confirmed at our meeting in 1889 by Mr. J. F. Hall, who had, for some considerable time previously, been working in the same direction, and had contemplated the application of nickel-steel to many of the purposes which had occurred to the former gentleman.

The study and practical application of nickel-steel appears to have been actively pursued since the reading of Mr. Riley's paper, not only in Great Britain, but also at the Le Creûsot Works, and considerable attention was attracted to this subject by a publication of the results of a trial instituted some months ago by the United States department of Naval Ordnance at Annapolis of a 10½-inch compound plate of Cammell's manufacture, in comparison with an all-steel plate and a nickel-steel plate of similar thickness, made by Messrs. Schneider. From a statement in the very interesting paper lately communicated to the Institution of Naval Architects by M. J. Barba of the Le Creûsot Works, on recent improvements in armour-plates, the authorities of that great establishment appear to have been under the impression that this was the first occasion on which a nickel-steel plate had received official trial, the fact being but little known that our Admiralty authorities experimented just a year ago upon a nickel-steel plate 4 inches thick, with very promising results, and that further trials of plates produced by several makers, containing different proportions of nickel, and treated in different ways, have since been pursued, with the result that the manufacture and treatment of plates of the material have already advanced considerably in this country. Some interesting information bearing upon this subject was elicited by the discussion which followed the reading of M. Barba's paper; the circumstance that the opinions expressed on the relative merits of the three different descriptions of plates, as based upon the experiments in the United States, and more recently in Russia, were somewhat conflicting, may be in part, at least, ascribable to the difficulty of obtaining really comparable results in trials of this description, and in part also to the circumstance pointed out by Mr. W. H. White, the Chief Constructor of the Navy, that the quality of armouring may reasonably be judged of from somewhat different standpoints according to the particular application for which it is intended.

At any rate, the value of nickel-steel in connection with naval architecture, with other constructive purposes, and with numerous additional applications, appears already so well established, that the question of securing supplies of nickel has assumed considerable importance, and it may be that ere long

the powers of the chemist may be severely taxed to supply good practical processes for the extraction of nickel from comparatively poor ores, in which important difficulties arise, from its association with several preponderating metals. In connection with this subject, I cannot refrain from referring to the new and high scientific interest which nickel has acquired in the eyes of the chemist through some remarkable recent discoveries made, in conjunction with Messrs. Langer and Quincke, by Mr. Ludwig Mond, whose name has for many years been prominently associated with some of the most important of recent progress in the development of the alkali industry. In the course of investigations upon the action of carbonic oxide upon finely-divided nickel at a high temperature, in which it was found that the metal had the power of separating carbon from that gas, with production of carbonic acid in place of the oxide, it was observed that if dry carbonic oxide were allowed to pass over the nickel at a temperature of about 100° C., the gas contained nickel, which was deposited from it in the metallic form if it was exposed to a higher heat (about 150°). A compound of carbonic oxide and nickel was, in fact, produced, which could be condensed to a colourless, volatile liquid, and even to a crystalline solid, by exposure of the so-called *nickel carbon oxide* to a sufficiently low temperature, and from which pure nickel could be readily recovered by the simple treatment just named.

It was ascertained by many experiments that other metals, such as cobalt, copper, iron, and platinum, were incapable of furnishing similar compounds; in fact, when a sample of purified cobalt was exposed to the proper temperature in carbonic oxide, a small quantity of metal was abstracted, and this proved to consist of traces of nickel which the cobalt had retained. Who can say that in these results, so remarkable from a scientific point of view, may not lurk the germs of a metallurgic process for the extraction of nickel from poor ores? One of the great characteristics of our age is the almost sudden opening up, from time to time, of new domains in the applied sciences, which, although the transient attention of workers in science may have, in years past, been attracted to them by the labours of some bold explorer, whose knowledge and whose appliances were at that time powerless to carry him on beyond the fringe of discovery, have con-

tinued to lie fallow until the intelligent application of new or improved methods of experiment result in their rapid cultivation, and in the utilisation of the fruits of scientific work, the germs of which were sown long since.

I feel, Gentlemen, that some apology is due from me to you for having allowed my great personal interest in the subjects which have been touched upon to betray me into wearying you with a somewhat disjointed discourse of inordinate length, embracing but little with which you were not already perfectly familiar. To the outside public the story of the intimate connection of the chemical and physical sciences with every step which has been, and is, taken in advance in the production and perfection of iron and of steel may embrace features of novelty and food for reflection; but to the Members of the Iron and Steel Institute it presents no new lesson for inculcation, for surely they themselves are in the forefront among the most active exponents of the truth, that the intimate blending of science with practice lies at the root of all industrial progress and success.

Sir JAMES KITSON, Bart., said it was not in order, and therefore it was not permitted, to discuss the President's address; but they would all agree that in it there was an observation which might be applied to the discourse to which they had just listened. It was said that Thomas Graham, the Master of the Mint, who, he was pleased to remember, was his master at University College, stated that well-stored and well-tempered dies coined more pieces than any other. They had in their President a well-stored and well-tempered die, and from the address which he had delivered to them they might hope to receive from his wide, extended, and profound knowledge of all subjects bearing on the chemistry of iron, lasting benefit to the Institute. He therefore submitted, "That the best thanks of the members of the Iron and Steel Institute be, and are, hereby tendered to Sir Frederick Abel, K.C.B., F.R.S., for his admirable and interesting address."

Sir LOWTHIAN BELL, Bart., F.R.S. (Past-President), seconded the vote of thanks. He attached, he said, great importance

to what had fallen from Sir James Kitson, as to the desirability of the Institute being presided over alternately by men of science and men of practice. He would not say anything that might disturb the feeling which he knew prevailed, that it was very useful to have the choice of their President vibrating as it were between men of science and men of practice. There was, however, another alternative, viz., when they could find science and practice united in one and the same person. He himself did not remember the time when the name of Abel as a man of science was not well known and respected. In the admirable address which they had just listened to, they had been told that their President, thirty-five years ago, had been considered eligible as an ambassador to a foreign court of ironmasters, in order to investigate and report on the processes of making iron carried on in other parts of the world.

The PRESIDENT said it was extremely gratifying to him to know that in what he had laid before the members in his address, which he feared must have wearied his audience, there had been some topics of interest, and possibly of novelty, to members of the Institute. He trusted that the kindness with which it had been received was an indication of the indulgence which he hoped would be accorded him during the next two years as President of the Institute.

PRESENTATION OF THE BESSEMER MEDAL.

The PRESIDENT had now his first duty as President to perform, viz., that of presenting the Bessemer gold medal, which had this year been bestowed upon Lord Armstrong for his eminent services in connection with the industries of iron and steel. Having been led by love of scientific pursuits to forsake the profession to which he had been trained for that in which for so many years he had held an exalted and illustrious position, Lord Armstrong had in very many directions contributed both directly and indirectly to the development of the industries of iron and steel. It was scarcely necessary to point to the influence which had been exercised upon the development and perfection of appli-

ances connected with those industries by Lord Armstrong's simple, philosophic, and thoroughly practical arrangements for storing and utilising hydraulic power. In the course of the manifold important applications which he had made of iron and steel to a variety of purposes of construction, he had done much to advance the mechanical uses of those materials; but it was more especially in connection with the construction of ordnance that he had so prominently distinguished himself, in the origination and development of methods of application, not merely of malleable iron, but also of steel. He believed it was a fact that when first Lord Armstrong devoted his attention to the production of material for a breech-loading gun, he turned to steel as the material which he would desire to apply; but our imperfect acquaintance at that time with the conditions to be fulfilled in the exercise of control over the physical properties of steel led him soon to discard that material in favour of malleable iron, with the application of which to manifold purposes he was so thoroughly acquainted, and he then developed, as was well known, a system of applying malleable iron to the construction of ordnance in such a manner that its available strength was utilised to the fullest extent, while its defects as a material for guns were minimised as far as possible. He need not dilate upon the many other important achievements which they owed to Lord Armstrong. He had made many scientific investigations bearing upon the properties of iron and of steel, such as his experiments on the elasticity and the first moving-point of iron and steel, concerning which Lord Armstrong had published some interesting results; especially important was his work in connection with the tempering and treatment of steel, that had led to the introduction of the process known as oil-hardening, which was in general use in connection with the construction of steel ordnance. Lord Armstrong's many-sided scientific tastes and high attainments were perhaps only thoroughly known to those who had the pleasure of his intimate acquaintance; but he might remind those present that, had the energies of Lord Armstrong not been diverted into the particular channels which had led to the high position occupied by him as an engineer, the world would certainly have counted him among the most eminent electricians of the day. He had now great pleasure in asking Lord Armstrong to accept the Bessemer medal.

Lord ARMSTRONG, C.B., said he was exceedingly obliged to the Council for having awarded to him the Bessemer medal, and to the President for the flattering terms in which he had presented it. The only drawback to the pleasure which he felt in receiving it was, that he considered it an honour that ought to be shared by others. It was, however, obviously impossible that a medal could be divided in due proportions according to the merit of different persons, and he must therefore regard himself as receiving it, partly in his individual capacity, and partly as representing his associates at Elswick. He again thanked them very kindly for this honour, and he wished every prosperity to the Institute in the future, especially during the presidency of Sir Frederick Abel, who had commenced his functions by giving them a most admirable and useful address.

The following paper was read :—

ON TESTS FOR STEEL USED IN THE MANUFACTURE OF ARTILLERY.

BY W. ANDERSON, D.C.L., M. INST. C.E.

THE physical and mechanical properties of steel depend upon so many conditions, that the greatest difficulty exists in devising tests which shall give the user of steel reasonable certainty as to the intrinsic qualities of his material, as well as some idea of its condition with reference to internal stresses.

At first sight it would appear that chemical analysis ought to provide the most certain indication of the nature of a specimen. The purchase and manufacture of very many substances are guided by chemical tests alone, and the results are eminently satisfactory. Why should not chemistry, in its present advanced state, render equally certain indications as to the qualities of steel?

The answer, I think, lies in the circumstance that the mechanical properties of steel, and of alloys generally, are affected in a remarkable manner by extremely minute quantities of substances associated with the dominant metal, by the relative proportions of these substances, by the changes in some, or in all, of them, produced by more or less rapid changes of temperature, which influence dissociation and reveal their effects by the singular phenomenon known as recalescence, which also indicates, though to a less degree, allotropic changes in some or in all of the components.

Chemical analysis sufficiently minute to detect even traces of every substance associated with iron, would be so tedious and costly as to be impracticable, and I fear that many years must pass away before chemical and physical science together will succeed in determining the laws which govern the mechanical properties of alloys.

Some advance has already been made by Professor Roberts-Austen,* who has shown that there exists a relation between the mechanical properties of some alloys and of the atomic volumes

* *Philosophical Transactions*, vol. clxxix. (1888). A. pp. 339–349.

of the substances of which they are composed, and I do not doubt but that farther investigations in this direction will enable metallurgists to predict, with some certainty, the effects of ingredients upon the mechanical properties of the substances to which they are added, but it is only those who have attempted such systematic work as Professor Roberts-Austen is now doing for the Alloys Research Committee of the Institution of Mechanical Engineers who can have any idea of the difficulties which surround the inquiry, chiefly arising from the practical impossibility of obtaining pure materials in sufficient quantity, owing to the liability to oxidation of the metals which are most used in the arts, to the disturbance caused by the occlusion of gases, and to other causes. The time which must necessarily elapse before a sufficient number of facts can be established to enable unassailable laws to be laid down, and the corresponding expense, are sufficient to deter the most enthusiastic investigator.

But assuming, even, that the laws are discovered, and that the effect of each constituent of steel can be foretold, there will still remain the necessity of determining by analysis the exact constituents of the sample, which will involve expense and loss of time that cannot be conceded.

For these reasons, and acting under the advice of the President, the specifications of gun-steel used in Her Majesty's service exclude all definitions of chemical composition, in so far, at any rate, as the proportions of the ordinary ingredients of steel, such as carbon, manganese, silicon, phosphorus, and sulphur, are concerned. The introduction of new materials, such as chromium, aluminium, or nickel, is, indeed, not forbidden, but special care is taken to ascertain their effects upon the mechanical properties of the metal before their use is sanctioned.

With respect to steel for lighter work, such as small arms, and especially for use in the production of swords and bayonets, some restrictions in chemical composition are imposed. In the former case, however, the percentage of carbon is defined with a view to the hardening which some portions of the components of a rifle have to undergo, and with reference to the durability of the barrels in regard to erosion by powder gases and abrasion by the bullets. In the case of swords, the difficulties of framing a satisfactory

specification are so great, that the subject was specially referred to Sir Frederick Bramwell and to Sir Benjamin Baker, and by them the nature of the steel to be used was, indeed, defined by its chemical composition, but with the sole view of securing uniformity in supply, the sword-maker being permitted to vary the components of the steel he proposed to use within certain limits. Once, however, the quality supplied is found suitable by the mechanical tests imposed, the chemical composition so selected is not to be departed from beyond reasonable limits of toleration; and I think that I may venture to affirm that the chemical tests for sword-steel were adopted only because it was found impossible to define the qualities required by physical tests alone, seeing that sword-blades have to be hardened and tempered, and are therefore subject to internal stresses, the nature and intensity of which certainly depend upon the chemical constituents of the steel, as well as upon the form of the blade and the mode of treatment.

It is not, I think, sufficiently realised that metals, and, indeed, most substances, are incapable of appreciable cubical compression, that is, change of volume under any stress that can in practice be brought to bear on them, under whatever conditions they may be, whether fluid, in the pasty state, at forging temperature, or cold. Like ice and water, steel and cast iron have a greater volume in the solid than in the liquid state, and therefore red hot solid cast iron or steel floats on the surface of the molten mass, and hence, to some extent, is due the sharpness with which the metal takes the form of the mould in casting.

The molecular motion in the metal, which results from the continued application of heat, culminating in producing a change from the solid to the fluid state, although it must constantly increase in energy, does not necessarily imply a greater mean distance between the molecules; in fact, the distance often becomes less, since the liquid is often more dense than the solid; hence it is probable that the motion of the atoms in the molecule are affected, which view certain other changes due to thermal influence seem to support.

In the process of solidification the outer surface sets first and becomes rigid, but as the cooling proceeds, in spite of the slight swelling of the mass due to solidification, the greater loss of volume arising from cooling asserts itself, and since the outside cannot be

drawn in altogether on account of its being set and comparatively cold, the inside of the mass is broken up into porous places or into hollows, so familiar in large castings of unequal thickness; and even if solution of continuity does not occur, the casting is in a condition of internal stress, which a trifle may develop into rupture. As the cooling proceeds, the inside contracts, and the outside, which had set in a stretched state, becomes violently compressed, while the inside remains in a state of tension; and if the material yields, the sudden release of the constraining the outside surface causes the parts to spring asunder with such violence that the surface stress, which was originally compressive, is suddenly turned into tension high enough to cause rupture with such energy as to be generally accompanied by a report.

In the case of wrought steel cooling suddenly from forging heat, similar action takes place. When annealed from below the temperature *b* of Chernoff, that is to say, below the temperature from which, in cooling gradually, crystallisation can take place, the fall of temperature on the outside and in the inside proceeds at nearly the same rate, and the contraction is consequently uniform throughout, and no internal stresses arise; but if heated to the same point and quickly immersed in oil or water, the surface is rendered rigid in every direction, and contracts upon the heated core, and this being incompressible, the surface has no alternative but to stretch. If it does this without fracture, the mass of metal is apparently uninjured; but should the tenacity be unequal to the stress, rupture takes place at once. Should the metal survive the violence it has been subjected to, the subsequent cooling will gradually relieve the tensile stress on the surface, and substitute a compressive one in all directions, while the core will be in a state of tension also in all directions, and in some cases these stresses become so severe that a slight disturbance of temperature, or the application of mechanical force, will determine rupture with more or less noise. This has been frequently observed in hardened armour-piercing shot, in steel coining and stamping dies, and even in oil-treated gun hoops and tubes, though made of mild and tough steel; and in these the late General Kalakoutsky * succeeded in accurately measuring the

* Investigations with the internal stresses in cast iron and steel. *The Engineer*, G. Reviers, 1888.

strains in a great number of instances, and in calculating the intensity and direction of the stresses which produced them.

In consequence of the conjugate nature of the stresses, the fractures are generally of a serrated, branching, and diagonal character. As there is no such thing as an absolute elastic limit, time, to some extent, obliterates the internal stresses; the metal slowly yields under them till a sort of armed neutrality is produced, so that after a few months' repose spontaneous fracture need hardly be dreaded; and for this reason dies and armour-piercing shot are kept in store for some time before being issued for service. The proper way, however, to restore neutrality, when hardness need not be retained, is to heat the steel to about the temperature *a* of Chernoff's scale (about 900° Fahr.), and suffer it to cool slowly. This is found to obliterate the internal stresses, while retaining, in a great measure, the so-called high elastic limit and ultimate strength which oil-hardening undoubtedly communicates.

If, however, the process of hardening has set up fissures or cracks, however minute, in the interior of the mass, and these are just as likely to be longitudinal as transverse, no subsequent annealing can repair the mischief done, and in this lies the great danger of oil-hardening. I attribute to it most of the failures which have occurred in artillery; and although all nations are in accord in practising the oil treatment of gun-steel, it is a remarkable fact that civil engineers do not feel justified in taking advantage of the undoubted increase of elastic and ultimate resistance communicated to steel by the process, on account, I presume, of the risks attending it.

There is no contesting the fact that the effects above described do follow sudden changes of temperature; but the action is by no means regular, because both the allotropic and chemical changes in the material are influenced not only by changes of temperature, but also by the state of pressure or tension which such changes tend to produce, so that certain combinations of pressure and temperature may develop much more marked effects than others. This is well illustrated by the changes which take place in drawing and rolling metals and their alloys; they are rendered hard and

brittle by mechanical tensions and pressures alone, and often to the same degree as by sudden cooling.

The difficulties which surround the framing of a specification for gun-steel were enhanced by the circumstance that till quite lately the steel-makers did not manufacture guns, at least for Her Majesty's service, while the gun-makers did not produce the steel which they required. Hence it became necessary to test the material practically in the rough forged state, and by a process which aimed more at ascertaining what the steel was likely to do when ultimately treated in the recognised manner, than to determine its properties in the particular state in which it was tested, which was not the condition in which it was to be built into the gun. The specification now in force in Her Majesty's service lays down that the specimens, which are to be cut from the components of the guns in a carefully specified manner, are to be 1 inch diameter by 4½ inches long; they are to be heated to 1425° Fahr., or a bright red, and quenched in oil of 65° Fahr. temperature, and left in the oil till cold. They are then to be turned down for a length of 2 inches to a diameter of 0·533 inch, and tested by tearing asunder. Bending tests after similar treatment on specimens 4½ inches long, 0·75 inch wide, and 0·375 inch thick, cut to these dimensions after being oil hardened, are also prescribed. In samples so small the probability is that the internal stresses set up by the oil treatment, even though it is not followed by annealing, are not very severe, and they are greatly relieved, in the specimens tested by tension, by turning off nearly a quarter of an inch all round the operative part. But the temperature at which the hardening is effected lies between two temperatures at which important molecular changes take place in the material. The researches of Gore, Barrett, Osmond, Professor Roberts-Austen, and others, show that at about bright red heat, or 1500° Fahr., iron undergoes a molecular change, made manifest by the evolution of heat sufficient, if not actually to raise the temperature of the metal, at any rate to retard its rate of cooling. Such evolution of heat must be due to molecular or atomic change, which is clearly reversible. In heating a bar, the rate of absorption must be momentarily increased at the point of recalescence; in other words, the specific heat of the material

is increased at a particular temperature; or rather, as a molecular change has taken place, the heat absorbed or evolved should be more correctly called latent. We have no information as to whether a change in specific gravity takes place also; but since liquid iron is more dense than solid, it seems probable that increase of density commences at the point of recalescence, and is maintained as the metal passes into the fluid state. A similar phenomenon is apparent in water, which attains its maximum density at 39° Fahr., and then commences to expand as the temperature falls, and maintains that expansion till converted into the ice into which it ultimately turns. Water colder than 39° Fahr. appears to be an allotropic form of water warmer than that temperature.

The allotropic change which takes place in iron at 1500° Fahr. is probably accompanied by a change in physical properties, producing what Osmond has called α and β irons. Apparently, when the change takes place in gradual cooling, the β iron, that of the higher temperature, and which Osmond conceives to have hard molecules, passes into the α state, in which he supposes the molecules to be soft. Cooled rapidly, in either state soft iron results; but in the presence of carbon or of some other substances, the β iron is supposed to retain some of its hard nature, and to be the cause of hardening in steel.

In addition to this change in the iron, which forms the main component of steel, it is now demonstrated by the researches of the President, Åkerman, Osmond, and others, that the carbon, at any rate of steel, exists in two conditions, namely, either in the form of a definite compound of carbon and iron dissolved in an excess of iron, or as finely subdivided carbon diffused through the mass, and that at certain temperatures association and dissociation take place, the combined carbon becomes diffused, and the diffused carbon combines. The act of combination being a chemical process, might be expected to declare itself in the evolution of heat, and the researches of Osmond, laid before this Institute last year, abundantly show that at about the temperature of 1200° Fahr., or red heat, such an evolution of heat does take place.

Struck by the importance of the researches to which I have drawn your attention, and imagining that the methods pursued by

Osmond opened up the possibility of arriving at a knowledge of the condition of large masses of steel with respect to their uniformity of composition and physical condition, I suggested to the Institution of Mechanical Engineers that it could not do better than institute a systematic research into this matter. The proposal was adopted with the utmost readiness; a strong committee, of which our President is a distinguished member, was formed, and Professor Roberts-Austen was requested, adequate assistance being provided, to undertake the work. He readily accepted the task, and I venture to think that already very encouraging success has been met with. It would obviously be improper for me to explain here the means by which the work is being carried out. A report will very shortly be presented to the Institution of Mechanical Engineers which will contain the fullest information, and I will therefore only state that Osmond's experiments have been repeated, the rate of cooling of specimens has been registered by the most ingenious automatic methods, and curves have been produced from which even an inexperienced eye may detect the two points to which I have drawn your attention. The mode of procedure requires but very small samples, and a few minutes suffice to obtain a record; so that I am sanguine that before very long a method will be arrived at by which it will be possible to determine the quality and conditions of masses of steel, from the mere shavings turned off, far more accurately and rapidly than by means of any test which we are able at present to apply; and this power is of vital importance now that we propose to build up guns of immense masses of steel, the quality of which, though it may be determinable by present methods at the ends, cannot be ascertained without great loss in other parts of their length.

The investigations prove, at any rate, that steel is being treated, or ill-treated, now at temperatures which lie between two critical points, separated from each other by only some 300° Fahr. It has to be treated in masses of ever-increasing magnitude, and the temperatures at which the hardening and annealing are performed can only be judged of by the eye—an extremely unsatisfactory method, considering how much the appearance of a heat is modified by the intensity of the light around. I cannot divest myself of

the feeling that the apparently capricious behaviour of steel is due not only to the internal stresses engendered by oil hardening, but also to the circumstance that the chemical condition of the steel, and its molecular structure, are greatly influenced by comparatively slight errors of judgment, or by carelessness in the adjustment of the temperatures at which the operations are performed.

The circumstance that within the last two or three years three important firms have undertaken the manufacture of heavy guns from steel of their own producing, and have introduced powerful forging presses, renders it possible to modify our specifications in the sense that more attention shall be paid to the nature of the steel employed, and to the mode of working it, than heretofore. It is in contemplation to provide that open-hearth steel only shall be used; that the ingots shall be treated in a special manner when hollow forgings are to be produced; that a certain minimum amount of work shall be put into the steel, and that annealing from a red heat, or about 900° Fahr., shall always be the last operation, even if the mechanical properties aimed at can be attained without hardening in oil or water.

It is remarkable that foreign nations appear to attach much more importance to determining the elastic limits than Her Majesty's service. The French and American specifications prescribe both the elastic limit and the ultimate strength. The Russian specification defines the elastic limit only, though the ultimate elongation per cent. is prescribed. I believe that the Germans follow the same rules, though I have been unable to obtain any direct information on this point. In Her Majesty's service a limit of permanent extension under a load of 21 tons per square inch is prescribed, and a note is to be taken of any yielding under a less load; but the term "elastic limit" is carefully excluded, on the ground that no such limit can, in fact, be defined.

All foreign nations seem to prescribe hardening in oil, though no mention is made of any particular temperatures, and in all cases the first and the last operation must be annealing, after which only the test-pieces are taken.

At the Abouchoff Steel Works, the hardening and annealing is practically one operation, the object to be treated being immersed in the oil only for a short period, the duration of which is a matter

of judgment, and depends upon the dimensions of the steel. It is then rapidly withdrawn, and returned to the heating furnace, where it is allowed to cool slowly.

It is impossible, within the limits of a paper suited to these meetings, to enter into all the details of the question I have ventured to bring before you. My object is to draw attention to the recent advances in the theory of steel, and to suggest how the knowledge, even now, in our possession must gradually affect our practical work. I trust that the discussion, which will no doubt arise, will give to the world the knowledge and experience which is so peculiarly the dower of the members of the Iron and Steel Institute.

DISCUSSION.

The PRESIDENT said that the interesting communication which Dr. Anderson had just given them raised so many important points upon which they would like to hear the views of experienced men working on the subject who were present at the meeting, that they ought to have a very interesting discussion, and he therefore now invited observations upon the paper.

Professor ROBERTS-AUSTEN, C.B., said he had but little to say in relation to this paper directly, because he should have some further remarks to make when he described M. Le Chatelier's apparatus, which was now before the members of the Institute, but he was glad to find that Dr. Anderson showed on the first page of his paper that he was more an allotropist than either M. Osmond or himself. Dr. Anderson said that so many of the elements present hidden in the iron probably assumed, as the temperature fell or rose, a state different from their former one. The fact that certain mechanical tests indicated the possibilities of using steel for a definite purpose better than similar evidence afforded by chemical analysis, probably meant that air-knowledge has been so carefully built up on a chemical basis that the physical side of the complex problems were probably, for the moment, the prominent ones. Chemical and physical research were equally important, and the possibility of predicting what use a steel might be applied to from merely mechanical tests was very much the line taken up by Deshayes and Lebasteur many years ago in connection with the 1878 Exhibition. Further developments of the work of a committee appointed by the Institution of Mechanical Engineers, to which Dr. Anderson had referred, could hardly be set forth until their report was published, but he hoped to have a few additional remarks to offer when he described certain apparatus he had to submit to the meeting.

The PRESIDENT said they had the great pleasure of counting M. Le Chatelier among those present, and no doubt he had some interesting observations to offer on the subjects touched upon by

Dr. Anderson in his paper. He was equally certain that if M. Le Chatelier had any hesitation in addressing them in English they would be only too glad to hear him speak in French.

M. LE CHATELIER said that at the present time he was engaged in determining the change in specific gravity that accompanies the molecular change of iron at 890° discovered by M. Osmond. The change in specific gravity, it is true, is very slight. It does not exceed $\frac{1}{1000}$, if, indeed, it is not nil. From 890° to 1100°, iron continues to expand with regularity. Above this temperature, experiments have not been made.

For the recalescence of steel, in the contraction observed on heating by Gore, Barrett has found an increase of density of $\frac{4}{1000}$ in a steel containing 0·9 per cent. of carbon. It should be noted that a change of volume measured on the whole of the mass is in reality produced exclusively in the carbide of iron, which represents but a portion of the weight of the steel. The change of volume of the carbide supposed to be isolated would therefore be much greater. By admitting the theory of Messrs. Sorby and Osmond of the cellular constitution of steel, in which the carbide of iron plays the part of a cement in relation to the grains of pure iron, it is possible to explain certain effects of tempering such as the increase of the limit of elasticity and accidental fractures.

In tempering, the change of the carbides of iron is not prevented. It is merely delayed, being produced at a much lower temperature. In order to prevent the change of the carbide of iron, and to obtain a hardening effect, it is necessary that the temperature should fall below 200° in a very short time—about two seconds, more or less, according to the nature of the impurities. This degree of rapidity is never attained in iron-hardening in large pieces. It may therefore be admitted that the change of the carbide invariably occurs.

This change in the volume of the cement, enveloping grains of pure iron that does not change, gives rise to internal tensions which are limited by the elasticity of the metal at the temperature under consideration. Now, from experiments made by my brother, M. A. Le Chatelier, marine engineer, it follows that the elastic limit of iron at 700° is almost nil, not exceeding 2 kilo-

grammes per square millimetre (1·27 tons per square inch), whilst at 300° it is not higher than at the ordinary temperature, and amounts to 30 kilogrammes (19 tons per square inch).

The change of the carbide at 700° does not develop any internal tensions, and does not cause an increase in the limit of elasticity of the metal. It would be quite different if, as the effect of rapid cooling, the change was only produced at 300°.

For the same reason, the change produced at high temperatures and slow cooling does not bring about rupture, because the metal is still very malleable, although at low temperatures it is not so. It is probable that in this case the cement becomes fissured in the interior, producing a similar effect to that observable in half-melted slag. The change, analogous to that of carbide of iron, of a small quantity of the silicate $SiO_2 2CaO$ produces internal tensions that renders the slag fragile.

The inevitable rupture of large pieces of steel hardened in water is due to the fact that the surface, if really hardened, is not affected by the sudden expansion produced in the interior, or it may be that the change of the carbide would be possible from a slower cooling. The value of the expansion given above approaches that of the cubic coefficient of elasticity of steel, and this shows that the pressure resulting from this expansion, being effected in a rigid envelope of invariable volume, would be 50 kilogrammes per square millimetre.

Mr. R. A. Hadfield said he had not had much experience in the manufacture of gun steel, and there were many eminent steelmakers present who could offer better observations than himself. He should, however, like to ask Dr. Anderson a question with reference to a remark in his paper that molten cast iron had a greater volume in the solid than in the liquid state. He wished to know if he considered that that applied to molten steel? He presumed that it did, but he did not know whether the point had yet been fully determined. Perhaps Mr. Wrightson, who was present, would offer some remarks on the subject, as he had made a considerable number of experiments in that direction. If so, could the difference be measured? It was especially important to steelfounders to know whether such expansion took place, as

in making steel castings they often found unaccountable cracks. If such expansion did take place, that might partly account for them. Generally, however, they had been put down to contraction rather than expansion. It might be that there was a double action, and it would be interesting to have the point thoroughly determined.

With reference to the remarks on the equilibrium of hard steel, the author had referred to the effect of unequal expansion and treatment during cooling in the matter of steel projectiles, in which, if heated and quickly immersed in oil or water, the surface is rendered rigid in every direction, and contracted upon the heated core, and this being incompressible the surface had no alternative but to stretch. If it did this without fracture, the mass of metal was apparently uninjured; but should the tenacity be unequal to the stress, rupture at once took place. Should the metal survive the violence it had been subjected to, the subsequent cooling would gradually relieve the tensile stress on the surface, and substitute the compressive one in all directions, while the core would be in a state of tension also in all directions. In some cases these stresses became so severe that a slight disturbance of temperature, or the application of mechanical force, would determine rupture with more or less noise. Mr. Hadfield held, however, that if equilibrium of contraction or expansion could be secured during cooling, it was astonishing how much punishing a steel shell would stand. His firm (Hadfield's Steel Foundry Company, Sheffield) had to supply the British Government with 6-inch shells that must penetrate 9-inch compound armour plates, having hard steel face-plates—some of the plates containing as much as $1\frac{1}{4}$ per cent. of carbon. This severe test was often gone through without the projectile sustaining any practical change of form. There was in the adjoining room a shell which had been subjected to this test. Still it was difficult to make a shell that would undergo such punishment, and there was often a considerable number of wasters.

As regards the effect of re-heating "quenched" material, Dr. Anderson had said he thought that the hardness imparted by such quenching was entirely removed by heating up to 900° F. On the previous day, when travelling to town with a Sheffield manufacturer who made large quantities of gun steel, he understood

him to say that if they tempered a piece of steel at 900°, 1000°, or 1200° F., they would not remove the amount of hardening produced by the quenching until the same degree of temperature was again reached. That was to say, to remove all traces of hardening it would be necessary to heat the steel again up to 900°, 1000°, or 1200° F., as the case might be. Hs should like to know what Dr. Anderson thought on that point.

Some reference was made in the paper to the English system of testing the elastic limit. He had the pleasure some few months back of seeing some tests made at the Bethlehem Iron Company's Gun Works in Bethlehem, U.S.A., and in determining the elastic limit as much as twenty minutes were required, the inspectors insisting upon that time being spent on the operation, instead of a few minutes or a shorter time as was done in this country. This was done in order to take a careful record of the sets produced by the different stresses. He, however, decidedly agreed with Dr. Anderson in thinking that the English system was the best, because the elastic limit of steel, without doubt, was very difficult to determine, and if it were done minutely enough, and in a very exact manner, it would be found that there was practically no elastic limit, as Dr. Anderson had pointed out. His own experiences in regard to oil-tempering were not large, but he could not help thinking that where the object was a toughening, and not a hardening one, it was much better to get the required quality of steel by varying its chemical composition. In other words, he thought that the steel would be more reliable and stronger if it were not oil-tempered. He knew it was rather heretical to say so, but he thought that the true way to get material in a state of equilibrium was simply by careful annealing and slow cooling, and to obtain a higher tensile strength, if it was wanted, by modifying the chemical composition. This plan had been followed by Sir John Fowler and Sir Benjamin Baker in fixing the specifications for certain portions of the steel used in the Forth Bridge, and with great success; that was, instead of using a very mild steel and getting stiffness by hardening and afterwards tempering or other similar means, they had used a harder steel, thus getting the required stiffer steel with higher tensile strength.

With regard to the use of the pyrometer in making observations

in treating steel. He had ventured to point out eighteen months or two years ago, that more attention should be paid to that point. He thought that it was of the greatest importance to determine accurately the temperature at which iron and steel were treated. It they could only get some system of ascertaining exactly the temperatures at which the material was dealt with—either heating or cooling—a great advance would be made in the art of steel making and steel treating. He was pleased to see that M. Le Chatelier was present, and he was sure that metallurgists were greatly indebted to him for the admirable instrument he had brought out, and also to Professor Roberts-Austen, who was pushing the matter so much in England. At present it was more a scientific instrument, but he believed that if it could be improved and simplified so as to be capable of being handled by workmen, great strides would be made. He thought Dr. Anderson was entitled to their hearty thanks for his admirable paper.

Mr. E. H. CARBUTT said that both the President and Dr. Anderson had referred to the question of oil-hardening; and he should be glad to know from Dr. Anderson if oil-hardening had been given up? Some years ago, at a discussion at the Institution of Civil Engineers, he had expressed a doubt as to that being a right method of treating steel; and he still entertained the same doubt. He rather agreed with Mr. Hadfield that oil-hardening was not the right method of treating a big gun-forging; and he should like to know, without inquiring into State secrets, whether oil-hardening was given up, or whether there was a tendency towards giving it up with big tubes? He thought that the method of heating and then cooling gradually would be a better method than oil-hardening.

Mr. RIDLEY said he thought the great thing wanted was to have an acknowledged rule for lowering the temperature so as to be able to ascertain the rate at which the material was cooled.

Mr. THOMAS WRIGHTSON said he regretted that he had not received an advance copy of the paper, as he might then have been able to say something about it. Dr. Anderson's account of the behaviour of a casting in cooling admirably described what

actually took place; the expansion and subsequent setting of the outside, then the expansion of the inside as it gradually cooled, through the higher grades of temperature, until the contraction commenced again, causing a tension in the interior which frequently led to rupture. But there was one statement in the paper which might (unintentionally) be misleading. The author had remarked that, "like water and ice, steel and cast iron have a greater volume in the solid than in the liquid state, and therefore red-hot solid cast iron or steel floats on the surface of the molten mass." That was true, but only to a limited extent. As a matter of fact, what might be called cold cast iron sank, but it rapidly rose in temperature, expanded, and came to the surface. He thought that was fully demonstrated by some experiments which he had made, and described in a paper that he had the honour of reading before the Institute some years ago. The experiment was frequently made by *throwing* a piece of iron into the molten iron. It was sure to go down and rise to the surface again immediately. It might be thought that it was simply the impetus that the iron had attained in falling that carried it down; but, as a matter of fact, if the iron was lowered upon a fork it was seen to go down following the fork, and in the course of a few seconds it came up again, proving that when cold, the iron was denser than liquid iron. The piece as it got hotter expanded, and rose a considerable distance above the surface of the metal; then it rapidly melted, joining the liquid mass, and becoming, of course, of the same volume. In the first place, the volume of the cold iron was really less; that is, the solid was denser than the molten iron, and as it increased in volume in consequence of the heat it rose to the surface, and gradually emerged above it. Any one could see by the distance that the piece of iron rose above the surface that it must be of considerably less density than the molten iron. After it reached the maximum volume it decreased and joined the liquid mass again. Mr. Hadfield had asked whether he (Mr. Wrightson) had extended his experiments at all into steel. He knew as a matter of fact that steel did float in the way that had been mentioned. Dr. Anderson had also referred to it in his paper; but so far as his (Mr. Wrightson's) experiments were concerned, he had not made quantitative experiments except with cast iron. He believed

that Sir Lowthian Bell had made some experiments soon after him, which confirmed the views that he (Mr. Wrightson) had expressed.

Mr. R. EDMONDS (Woolwich Arsenal) said he did not come to the meeting with any intention of saying anything whatever on this subject, but it was one upon which he had been working for, he should say, thirty years. It was, he thought, about that time since he first began testing material for artillery. He would like to call attention to one of the things he ascertained almost at that early period. He thought it was about 1862 or 1863 that the oil-hardening of steel was just coming into vogue. He was doing it then, he thought, for Sir William Armstrong, and he had to make a great many experiments. He did them with all the care he could apply. At that time the apparatus was not so scientific or minute as at the present time, but one of his objects was to find out the difference between steel in its unhardened state and after it had been oil-hardened. For this purpose a great many experiments were made, and amongst others a series of experiments were made with specimens. He would say they were only 4 inches long between their shoulders. He had a great number of gauges made, each being one-thousandth of an inch larger than the predecessor. He made these experiments personally. He had to lie on the floor with a piece of carpet under him, and gloves on his hands in order not to impart any heat to the gauges. He found that the great difference between the unhardened and the hardened steel was in its elastic limit. The unhardened steel would go up to about 13 tons, and then it would receive a permanent elongation. It would break probably at 30 tons. These specimens were all cut from the same piece of steel, so as to be as uniform as possible. The hardened steel would go up to 31 tons before permanent extension, and would break at 45 tons. But what he wanted to bring out, because he did not think it was generally known, was that the modulus of elasticity was scarcely altered by the process. For instance, if they had 12 tons per square inch upon the specimen of the soft steel, it would stretch a certain proportion of its length, and if they put 12 tons on the oil-hardened specimen, it would stretch practically the same. But the great difference

was this, that the unhardened steel, when they got up to 13 tons per square inch, received immediately after that permanent elongation, but with oil-hardened steel they might go up to 31 tons before it received permanent elongation. There, he believed, was the great benefit they obtained from the oil-hardening. It was because the steel absorbed the work that was put into it before it yielded permanently. They could see that the difference between 13 and 31 was very nearly two and a half times as strong as the unhardened steel.

It had been said they could produce steel that would do that without oil-hardening: let them do it, and he was sure they did not want to have oil-hardening, if they could get the proper quality of steel without it. Another point was, why did not engineers in general use the oil-hardening process for the steel they used in manufacture? There was a very good reason for that, and it was this. In guns they had forms of steel which were very fairly uniform and symmetrical; they were mostly in the shape of hollow cylinders; but in the arts, in bridges, and structures of all kinds, the material was used in so many shapes, and the material was so very irregular in form, that they would be likely to get internal strains in consequence of that irregularity. One thing that it might be used for was double-headed rails, but for brackets, and girders, and other articles used in engineering constructions, he thought it would be simply ruinous to use the process of oil-hardening. He thought that was one of the reasons why engineers did not use that particular process. There had been one or two remarks made about the change of form through the oil-hardening process. Dr. Anderson might have mentioned that the length of a tube was sometimes taken before it was oil-hardened. In some of the larger tubes—and it was not in isolated cases, but in a number of cases—it was found that the oil-hardened tube would be very nearly half an inch shorter after it was hardened than it was before. He was now speaking of a tube for a 68-ton gun, a tube probably 30 feet long. They varied from 3½ to 4½ tenths before and after hardening. The *rationalé* was very simple when understood. As stated in the paper, while the material was all hot it was all in an expanded state; when it was dipped into the oil the outside was cooled, and if it were a hollow cylinder, the inside also,

leaving the internal parts of the metal still at a red heat. The surfaces shortened very much in cooling, and as there was very little volumetric compression, the metal inside was compressed endways, and the sides being long, they were pushed in. After that, as the interior cooled, it shortened, and the outsides, which were in a state of tension, were then pulled down into a state of compression—the result being they got a long tube nearly half-an-inch shorter after oil-hardening than it was before. The question might be asked, "Suppose you anneal this tube, do you undo that?" He thought they probably relieved the internal strains, but did not increase the length of the tube. It was found that practically there was no difference between the tube after it was annealed and as it was before; consequently, though the internal strains in the material might be removed they had not undone what was done by the hardening process.

Mr. JAMES RILEY—Annealed at what temperature?

Mr. EDMONDS said the temperature was between 900° and 1000° Fahr. With reference to the time for relieving those temperatures, he believed it was a well-known fact, even with the old cast-iron guns, that it was found very much better to let them lie about for three or four years before they were used. He thought it was found that guns that had been treated in that way were very much less liable to burst than other guns. With reference to getting steel with no oil-hardening, and yet with the same strength as the other, it must not be forgotten that what was wanted was immunity from cracking. Mr. Hadfield said he made hard steel, but it was very liable to crack, not by oil-hardening, but from its own characteristics, and if they did not get steel that would not crack when it was not oil-hardened, they might as well keep to their oil-hardening. The failures from oil-hardening were not very many. He admitted at once that they were very serious. When a gun burst it was a very serious matter, and therefore they wanted to eliminate the thing entirely, but the accidents that had happened could almost be counted on the fingers. And not only that, but he thought that in only two or three cases had they been on service. Nearly all had been in the course of manufacture or at proof. Of course, in the manu-

facture they found it out, and the proof was for the purpose of testing all the parts. Consequently they were not in such a bad state as might be thought. There had been some very peculiar actions in reference to steel in some hoops going before they were put on guns, but he did not know that any of them had gone after they had been annealed. They had had hoops which talked, as it was called—that was, that after they had been oil-hardened, a noise would be heard, a kind of report. There was one particular instance some time ago. A hoop made a report, which was repeated. The hoop was examined very carefully, and after a little while they found a crack outside, and then another. That was before it was put on a gun, and before it was annealed. He only wished to point out that these things did happen before they got into the ships or into the fortresses. They happened during the course of manufacture. He thought a great deal was to be done by the manner of forging. He thought he had stated before in that room that he preferred the press to the steam-hammer, and one of the reasons was that with the steam-press they did not have to keep the material heated for nearly so long a time. The work was done probably in one-fourth or one-fifth part of the time, and therefore the material was not heated such a long time. He therefore thought the forging press was the means by which steel forgings should be made for ordnance.

Mr. J. F. Hall said he had only had the paper in his hands a few minutes, but from what he had seen of it he thought it was a very valuable paper, and showed that the knowledge of the use of steel by the authorities at Woolwich was evidently improving. There was a paragraph (p. 64) which was so interesting that he should like to be permitted to read it again:—"If, however, the process of hardening has set up fissures or cracks, however minute, in the interior of the mass, and these are just as likely to be longitudinal as transverse, no subsequent annealing can repair the mischief done, and in this lies the great danger of oil-hardening. I attribute to it most of the failures which have occurred in artillery." In reference to the treatment of steel for guns, he thought those remarks were the most sensible he had ever seen. They all knew the difficulties experienced by manufacturers of large ingots

of steel; but with the assistance they now had of ingredients like manganese, silicon, and aluminium, they were able to do what they could not do some years ago, and they generally made the large ingots solid; nevertheless, there was always a risk of some little flaws creeping into the ingots, whatever care might be taken. The flaw was not welded up, but it existed, although it was difficult to be seen with the naked eye. Subsequently, if that steel was oil-hardened, the oil would be sure to find it out; it was not improved, but the danger of the flaw was considerably increased. That was the weak point of the whole gun. However much the main material was strengthened, what did it matter if a flaw existed which made the gun weaker than before at one particular point? He had always maintained that oil-hardening was a very dangerous process for that very reason, and he was only too pleased to find that Dr. Anderson had realised the fact and put it in the paper in the way he had done. Not only the Institute, but the entire country, ought to feel greatly indebted to him for having investigated the matter as he had done, and brought it forward for discussion.

Mr. James Riley said there was another matter for which they ought to express their obligations to Dr. Anderson. This paper was undoubtedly a sign of the times in this sense, that those of them who were engaged in the manufacture of steel must look ahead to what they were to expect shortly. For a good many years they had been subject to tests in many directions, and in the future it was quite evident that they were to be tested still more. This might be looked upon with apprehension from one point of view, but those of them who had read the paper or heard the remarks which had been made in the room that morning would really take the lesson to heart, and would be preparing for what was to come by improving their processes so as to attain the high standard which was being erected for them.

Mr. Jeremiah Head said that much had been said in the course of the discussion about the spontaneous cracks which occasionally occur in steel, whether in the form of ingots, castings, or plates. It was pretty generally known that they were almost always clean cracks—that was, there were no signs of any contraction of

the metal at the two edges, notwithstanding that they had previously been strained up to the point of rupture. If a piece were cut from near where such cracks had taken place, it almost always showed a considerable power of contraction when tested, up to 50 per cent. of its original area, and perhaps more. To his mind, the most mysterious circumstance in connection with such events was the absence of any evidence of ductility when they occurred, though there was an abundance of such evidence obtainable afterwards. Of course, if the metal did always contract, there would be no cracks. It would be a matter of great interest if Dr. Anderson would give the meeting the benefit of his views on the subject.

Mr. WESTON SMITH said he should like to ask Dr. Anderson if he had had any experience as to the effect of vibration after hardening? In the course of experiments at Landore some years ago on a small scale, he (Mr. Weston Smith) discovered that by violent vibration after tempering, the entire effects of the tempering were done away with. That might have an important bearing on oil-hardening in the manufacture of a gun. He also wished to ask Dr. Anderson a question with regard to the selection of test-pieces. He remembered, in the case of some solid jacket-forgings, about 2 feet in diameter, that were ultimately rejected, in which the test-pieces were specified to be taken out of the heart of the forging, that the tests were considerably in excess of the then requirements in the part immediately alongside the bore of the gun. It seemed a trifle hard on the steel, and also on steel manufacturers, that tests should be taken from, and perfection insisted upon in that part of the forging which would not finally become incorporated in the gun.

Mr. G. J. SNELUS had not had the opportunity of reading the paper, but there was one paragraph that had caught his eye, and to which Mr. Hall had drawn attention in a way that it deserved. He confessed he had always felt a great apprehension as to the effect of oil-hardening upon steel. He did not think that metal of that kind could be submitted to any sudden strain without receiving some harm. It was known by manufacturers that if cold ingots were put into a hot furnace they would suddenly crack

and be heard to go off like guns. He thought that was only an extreme case of what happened when hot steel was put into a cold fluid; and although they might by that means effect a certain result in increasing the tensile strain, he could not help thinking that internal strains were set up that were most dangerous; and when to the effect of those internal strains upon the solid metal they added the effect of the unsolid metal, to which Mr. Hall had drawn attention, and which, unfortunately, manufacturers had hitherto been unable to avoid, he thought that any process of that kind must have very serious effects,—if not always, certainly sometimes,—and that in all probability that treatment did account for many of the unfortunate failures that had occurred. There was another point to which he should like to call attention. It had been omitted from the paper, no doubt unintentionally, and probably they would be told that great attention was being paid to it. Dr. Anderson had said that they could not depend upon chemical analysis as a test applied to steel. He (Mr. Snelus), as a chemist, was anxious to defend somewhat chemical analysis, but he wished to point out one condition of the chemistry of steel which he was afraid had been lost sight of in discussions that had recently taken place, although he had no doubt that those interested in the matter were giving it full attention. He meant the segregation of those elements which were found in steel, and conferred upon it very important physical properties. He referred principally to phosphorus and those hardening elements which, when in excess, caused very brittle steel indeed. In making the large masses for guns, they had just the condition where that liquation of the elements came into play. He knew that in some of those large masses of steel the phosphorus had gone up from ·05 in average steel to 1 per cent. in the centre of the steel. He had been rather struck with the fact, and it had been recalled to his mind, because he had lately been making experiments upon an alloy of iron with another metal, in which that curious phenomenon had revealed itself in a marked manner. In the case of an alloy of iron and zinc he had found that by simply casting a well-mixed alloy in a chill mould such was the effect of the chill that the crystallisable metal separated on the outside, while the least crystallisable metal was suddenly squeezed into the centre, with the result that there was an alloy of iron

and zinc on the outside with 6 per cent. of iron in it, and an alloy inside with 13 per cent. of iron.

On another occasion he had found an alloy that had an average of 13 per cent. of iron in it, and by simply suddenly cooling in that way the rich iron alloy was squeezed into the centre to the extent of giving an alloy of 18 per cent. of iron, while the less rich iron alloy was left outside. They had not given enough attention to the question of the segregation of the metalloids, particularly in the case of steel, and he thought it would be well if it was still further followed up. He thought that Professor Roberts-Austen and M. Chatelier, with their beautiful instrument for ascertaining temperatures at very high points, had introduced a method which would be extremely valuable. But they should look, not only to the effect of physical changes, but still more than they had done to the effect of the various bodies and the chemical result which they produced upon the alloy under treatment. Many years ago he had the opportunity of studying the effect of phosphorus upon steel used for cutlery purposes, and he came to the conclusion that even so little as ·01 per cent. of phosphorus was just that which prevented the making of good cutlery steel out of Cumberland hematite, whereas it could be made out of Swedish iron; and if that small quantity of phosphorus enabled them to get a keen cutting edge which would stand where they could not get it before with the larger quantity, surely it was immensely more important to follow that effect in those large masses of steel where they had seen the phosphorus might accumulate from ·05 per cent. to 1 per cent. in some portions. That brought him to another point, the question of the specimens which were used for testing. He understood that the specimens used for testing were tempered in the same way in which the gun had to be tempered; but if they considered for a moment that in dealing with those small masses the effect of surface-action on the cooling metal could produce a result in the centre of the small piece with comparative ease, while the effect on the immensely large mass might be very little in the centre, he thought they would admit that taking small specimens and treating them in the same manner in which they treated the large one, and then assuming that the effect was the same in both cases, was hardly to be relied upon. The only way to ascer-

tain the effect of cooling a large mass in oil was to cut the mass up and see whether the effect of the oil had reached the centre or not. He thought if it had reached the centre it had reached it in a peculiar way—the way that Dr. Anderson had shown—and had done harm rather than good.

Dr. ANDERSON, replying on the discussion, said he thought that the observations which M. le Chatelier had made confirmed those of Mr. Wrightson and Sir Lowthian Bell as to the volume of steel and of cast iron being greater in the solid than the fluid mass when the temperatures were nearly the same. When the metal was cold the volume of the solid was less, no doubt, but as it got heated, apparently up to a cherry red, it began to float, and after that the volume was decidedly greater than that of the molten metal. Of course this fact, not generally known, had an important bearing upon the subject of the solidification of steel, to which he had drawn attention. What he had endeavoured to show in the paper was confirmed by Mr. Hadfield's statement, that he found great difficulty in producing armour-piercing shells, —that he had a good many failures before he had one success. This was commonly the case also with ordinary steel castings, where the form and proportions had not unfrequently to be modified to ensure sound work. He thought, with regard to hardened shells, that the difficulty arose from the circumstance that they were dealing with the projectile at temperatures in which changes in the metal took place, dependent on various circumstances, and the difficulty lay in hitting off the temperature at which the changes were favourable to the result that it was sought to obtain. He believed that the *rationalé* or theory of the difficulty was that they were obliged to work within a narrow range of temperature which it was impossible to measure accurately, and in which the various changes alluded to in the paper took place—changes in the chemical composition of the steel, as well as those connected with the allotropic forms of iron. With respect to the modulus of elasticity, his experience agreed with that of Mr. Edmonds. It was astonishing how much ignorance there was on the subject. He had heard it said over and over again "that such an object bent or yielded because the steel was too soft," but when asked what softness meant,

the answer invariably was that soft steel would of course stretch more per ton than hard steel, whereas the fact was that within the elastic limit there was no difference whatever in the stretching per ton per square inch between the softest gun steel and the hardest tool steel. The modulus of elasticity was practically the same. Recently Captain Younghusband, the Superintendent of the Royal Gun Factory, had made some experiments with the view of determining that very point, on rods, if he remembered rightly, about 100 inches long, of different kinds of steel, in the soft state and hardened. Similar experiments had also been made at the Royal Small Arms Factory at Enfield with sword steel. In both cases it was found that the steel would yield to the same extent under the same load if not strained beyond the so-called elastic limit. In reply to Mr. Carbutt, he would say that oil-hardening had not as yet been given up, but there was a tendency not to insist upon it if the mechanical properties required in the steel could be obtained by other means. Annealing from about 900° F. in all cases had been adopted as a final operation. The difficulty seemed to be that all nations had adopted the process of oil-hardening, and it was hard to imagine that they would stick to a process which had not some virtue in it. He himself, in common apparently with all civil engineers, had always been greatly against the practice, thinking that the danger inherent to the process was greater than the advantage. Knowing the great improvements in the manufacture of steel which had taken place, he thought it very likely that the objects aimed at would soon be attained by other means, and that oil-hardening would then be given up.

He would like to explain that the paper which he had just read was, to a certain extent, premature. When the President asked him to prepare it, he thought that a new specification for gun steel, which had been for some time in contemplation, would have been adopted into the service, but for various reasons this had not taken place, and as it was a rule of the service that matters still under consideration were not to be divulged, his hands had been unexpectedly tied, and he had to make the best of a situation which prevented him from referring to a subject which he particularly wanted to bring before the Institute. The tendency, he might say, was to test the steel in the condition in which it

was going to be built into the gun, and in those cases where the steel maker was also the gun maker, of course the manufacturer would have the whole process under his own control, and he might produce the steel in any way he liked, provided it would pass the test, by samples cut from the steel, after final treatment. With regard to Mr. Head's question, he did not quite catch the meaning of it. Steel which cracked spontaneously usually opened out, and changed in form, so that the fractured surfaces would not fit together again. From some recent experiments, which had been made at the Royal Gun Factories, of cutting slices from the ends of hoops which had been oil-hardened, they found that if rings which had been oil-hardened, without subsequent annealing, were cut radially through one side they closed or opened (he forgot which), to a marked degree, proving the existence of internal stresses; but if the rings were annealed after oil-hardening, from about 900° Fahr., it was found that no movement took place on cutting through, thus indicating that annealing had the effect of removing the internal stresses, and the mischief arising from them, provided always that there had been no solution of continuity anywhere. Of course, if hidden internal fractures had taken place, and such cases were not uncommon, nothing could repair the damage. He was not able to answer Mr. Weston Smith's question about the effects of vibration in reducing hardening. Guns were not subjected to vibration in the sense in which he spoke of it, that was, from long-continued vibration. As far as he knew, test specimens taken from guns which had been in use for some time showed no marked difference from the original specimens of the steel from which the gun had been made. He did not think the comparatively small amount of use that a gun was subjected to was sufficient to make any difference in the physical state of the steel.

He was very glad of the opportunity of tendering his thanks personally to M. le Chatelier, who did them the honour of being present at that meeting, because he really believed that the difficulty which Mr. Snelus had pointed out, of ascertaining in the great masses of steel used now—30 feet long, for instance—how they could be reasonably certain that the bulk of the steel was the same as that at the two ends where alone it could be tested, would be solved by the aid of the Chatelier pyro-

meter. If his anticipations were correct, by selecting shavings as the article was being bored or turned, and noting the form of the curve of cooling, and the position and form of the kinks, as had been done by Mr. Roberts-Austen with M. le Chatelier's pyrometer, they would then be able to form a good opinion as to whether there was any want of uniformity in the nature of the steel. A change in composition or in physical state was sure to reveal itself in the position of the two kinks, one of which showed the allotropic change in the iron, and the other indicated the point at which the chemical change in the steel took place. If they took specimens all along the length of a large forging, and found that the curves were identical all through, they might be pretty sure that the steel was of uniform composition from end to end, and in a uniform condition. Although the process might not give them positive information, it would give comparative indication from which inferences might be drawn as to changes caused by liquation, or any other disturbing causes, or that the steel was of the same quality from one end to the other. That was an enormous gain. It must be remembered also that comparatively unskilled hands could do this by means of M. le Chatelier's apparatus in a few minutes. If he remembered rightly, Mr. Roberts-Austen told him it took him about twenty minutes to make an experiment; whereas the preparation of microscopical specimens, and the making of chemical analysis to obtain the same object, would take a long time, and therefore be difficult of application. With respect to Mr. Snelus's remarks, he was quite sure the President would bear him out when he said that he had the most profound respect for chemical analysis, but he thought that it had its proper limits. The Ordnance Factories were guided by the chemical analysis, not only in the treatment of steel, but in all their metallurgical operations; but the point which he had insisted on was, that chemical analysis might be misleading unless it was very complete, because apparently trifling quantities of substances were capable of producing very important results.

The PRESIDENT said he was glad to find that his expectations had been amply fulfilled, and that the paper which he induced Dr. Anderson to be good enough to prepare, although it was not

so complete as he (Dr. Anderson) had hoped, had elicited an instructive discussion. He was sure they were all indebted to him for the trouble he had taken, and he asked them to agree to a hearty vote of thanks to Dr. Anderson.

CORRESPONDENCE.

Mr. W. H. White, C.B., F.R.S. (Director of Naval Construction) remarks that he had been requested to submit any observations he might have to offer on this paper of Dr. Anderson's. He desired to express his high appreciation of the value of the communication, and of the admirable form in which it has been given.

In connection with their recent experiments on armour, the Admiralty had had many opportunities of observing the effect of treatment upon plates of moderate thickness, and some of these results fully support the view which Dr. Anderson expresses, viz., that oil-hardening, unless carefully conducted, and followed by annealing, may do harm rather than good to steel plates subjected to the attack of projectiles moving at high velocities.

On steel armour-plates of ordinary quality up to 5 or 6 inches in thickness, it had been decided, therefore, not to insist on oil-hardening. For ordinary steel plates of greater thicknesses, and for alloys of nickel and steel, oil-hardening, followed by careful annealing, had been shown to be beneficial, particularly in increasing toughness, and reducing the tendency to cracking under impact.

It might be added that when mild steel began to be used for shipbuilding in the Royal Navy, annealing after working plates or bars was largely practised, on the recommendation of the manufacturers of steel. In many cases, however, the so-called processes of annealing were proved to have done harm rather than good, particularly as the result of over-heating certain portions in the furnaces. Consequently, as experience had increased, annealing had been dispensed with in nearly all the operations of the ship-yard; and little more care was now necessary in treating mild steel than was formerly taken in treating iron.

THURSDAY, MAY 7TH.

The proceedings of the Institute were resumed to-day—Sir FREDERICK ABEL, K.C.B., F.R.S., President, in the chair.

AUTOMATIC METHODS OF OBSERVATION IN THE USE OF THE LE CHATELIER PYROMETER.

Professor ROBERTS-AUSTEN, C.B., F.R.S., in submitting some observations on this subject, pointed out that a really trustworthy pyrometer was much needed—one which would be capable of affording reliable indications at the higher ranges of temperature usually met with in metallurgical work. The Siemens pyrometer, admirable in its way, depended, as was well known, on the variations of the resistance of platinum wire under the influence of alternations of temperature. It was an expensive appliance, and although a committee of the British Association showed that the mistrust with which it was regarded was to a great extent unfounded, its use is in many ways inconvenient. Since about the year 1830 physicists had told them that they ought to use thermo-junctions for the measurement of high temperatures, the action of the thermo-junction depending on the fact that a current of electricity is generated by heating two dissimilar metals. But it was not until Professor le Chatelier placed at their disposal an admirable thermo-junction, that the problem could be considered to be really satisfactorily settled. Professor le Chatelier's thermo-couple consists of a platinum wire simply twisted with, or soldered to, another wire of platinum containing 10 per cent. of rhodium. When this thermo-junction is heated a current of electricity is generated, and the current passes round a dead beat galvanometer, the amount of deflection of the galvanometer mirror being proportional to the heat applied to the thermo-junction. The alloy of platinum and rhodium is uniform; in composition it does not undergo secular change by repeated heatings and coolings; it always behaves in a most satisfactory manner, and gives the most trustworthy results.

But then the question arose, How is any particular couple to be calibrated? This is done by taking certain known tem-

peratures, which have already been determined by the aid of the air-thermometer, up to the temperature at which silver fused or zinc boiled, 940° C. That is easy enough. There is a great concensus of opinion as to the melting point of silver, or the boiling point of zinc, but it was the temperatures beyond that were really difficult. Violle had given some determinations, such as the melting point of gold 1045, and the melting point of palladium 1500, which might be trusted with but little reser-

CALIBRATION OF PYROMETER.

CURVE FOR USE WITH PHOTOGRAPHIC RECORDS.

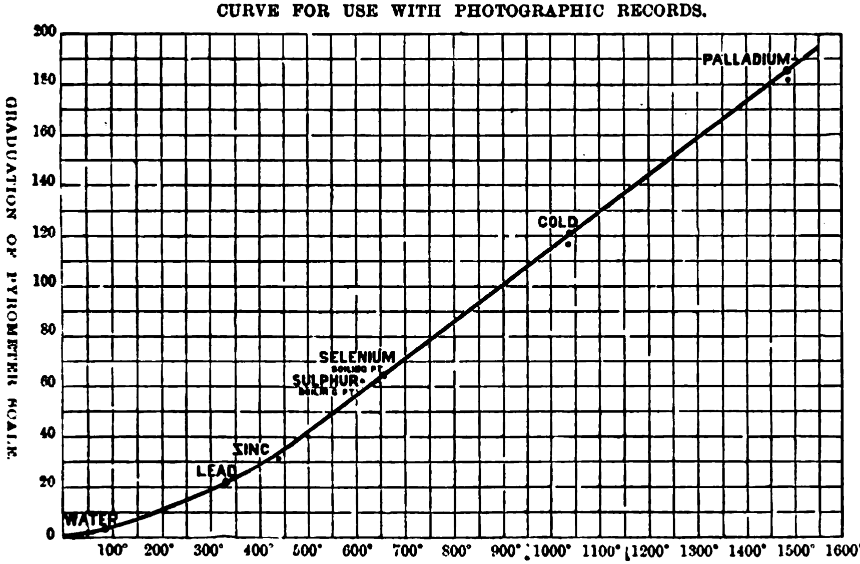


FIG. 1.

vation. At any rate, his are the most trustworthy determinations of high temperatures at our disposal for calibrating the pyrometer. This is shown by reference to the diagram (Fig. 1), in which certain known temperatures, and the deviations of the spot of light from the galvanometer mirror, were taken as co-ordinates. The little wire-junction is plunged in the metal under examination, which is melted, and the curve showed the really remarkable way in which, taking the known temperatures as carefully as they could, all the readings of the pyrometer fell

into line when plotted in a curve. It might be asked, How could it be ascertained whether a certain indication of the galvanometer mirror corresponded to the melting point of gold? Nothing is simpler. Take a little button of gold, melt it, and place a thermo-junction in it, and watch the spot of light as it traverses a graduated scale. As the metal was cooling suddenly they would find a point of arrest as sharply defined as possible, and it was that point of arrest which indicated the point of the solidification of gold. In heating the globule up again they would find an arrest at the point which marked the melting point. In the case of palladium they had a metal very difficult to fuse, but for the purpose of calibration nothing was easier than to proceed as follows. Scoop a little hole in a piece of charcoal, and place a globule of palladium in it, put the thermo-junction in that close to the globule of palladium, and turn a little jet of oxygen on the hole in the charcoal, which had been previously made red-hot, and they could then determine the melting point of the palladium without difficulty. Violle's experiments gave the melting point of palladium as 1500° C., and it is curious to note that when the melting point is determined by the pyrometer the indications fall directly into their place on a continuous curve, as the diagram shows. The original papers must be referred to for further details as to the method of calibration. What he was anxious to bring before them on that occasion was the method of recording the results of pyrometic measurement. He had the good fortune to show the apparatus to Professor le Chatelier on the previous evening at the Royal Society, and the Professor expressed his entire approval of the method which had been adopted, and he need hardly say that this had encouraged him greatly in proceeding to arrange for future experiments.

The apparatus consists of a galvanometer of the Déprez and d'Arsonval type, enclosed in a large camera; a fixed mirror F being placed below the movable mirror M of the galvanometer, so that the light from the lime cylinder L, reflected in the mirror H, passes to both mirrors, F and M, and is reflected in the direction of a fine horizontal slit, AB, behind which a sensitised photographic plate, C, is drawn vertically, past the slit, by means of gearing, D, driven by clockwork. The ray from the fixed mirror

is interrupted periodically by the vane, E, and a beaded datum line is given which enables any irregularity in the advance of the plate to be detected.

The amount of divergence from its datum line of the spot of light reflected by the movable mirror at any given moment bears a relation (which can readily be found by calibration) to the temperature to which the thermo-junction X is heated, and variations of temperature are recorded by a curve which is the resultant of the upward movement of the plate and the hori-

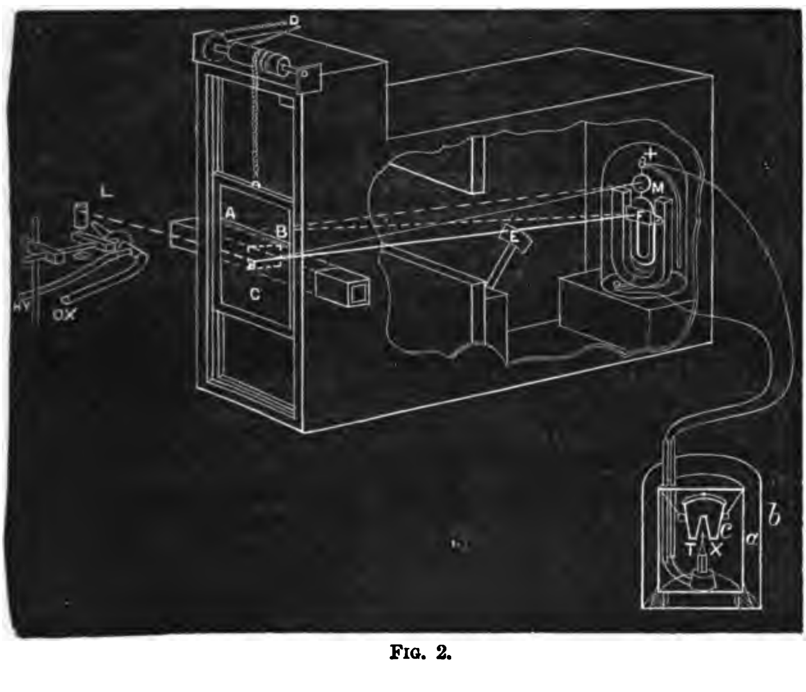


FIG. 2.

zontal movement of the spot of light. The complete arrangement is shown in the diagram (Fig. 2).

The thermo-junction X is inserted in a tubulure of a specially constructed crucible of plumbago, which contains about 5 oz. of pure molten gold, and is allowed to cool down slowly inside a vessel of silver, 105 mm. diameter, and polished internally.

If the thermo-junction was immersed, or brought into contact with the mass of metal which was being heated to melting, they would get a sinuous line traced on the advancing plate by the passage of the spot of light from the movable mirror in its efforts to get back to its zero. The photographic method of recording gave a very delicate means of ascertaining any molecular changes that might take place in iron or other metals; but that matter had been dealt with by the Committee of the Institution of Mechanical Engineers, and he did not wish to refer to it at any greater length. But he did think—and Sir Lowthian Bell had satisfied himself that the method might be adopted—that they had in the little thermo pile an extremely accurate mode of measuring the temperatures of effluent gases from furnaces, hot-blast mains, or any source of heat, even furnaces themselves, that it might be desirable for metallurgists to measure. He thought he had better leave the matter where it was, and answer afterwards any questions on points that might suggest themselves to the members.

Sir Lowthian Bell, Bart., said he had been engaged for the last twenty years in researches in which the rapid and correct ascertainment of high temperatures was indispensable. Unfortunately he had never been able to obtain any apparatus in which these two conditions were combined until he had procured the instrument described by Professor Roberts-Austen, which, so far as his own experience enabled him to judge, seemed to fulfil all the conditions which had hitherto been wanting. The best form of apparatus up to the present time was what was generally known as the Siemens pyrometer, in which the heat acquired by a copper ball was communicated to a given quantity of water, from which the temperature was calculated and read off by means of a specially constructed thermometer. As a rule, however, it might be taken that seven or eight minutes were required in order to heat the copper ball to the temperature of the substance under examination. During that time great changes might be taking place, so that they were never sure that the temperature read off was perfectly correct, an objection which did not apply to M. le Chatelier's form of appa-

ratus. It had also another very great advantage. By means of proper contrivances, they could take the temperature of furnaces —he could not say at what distance from the point of observation—but they had in the office of the Clarence Works an instrument which indicated the temperature of the blast entering a furnace at a distance of something like 100 or 200 yards. That this distance had not interfered with its correctness had been verified by removing the pyrometer close to the furnace, when no appreciable difference in its indications was found to exist. Guided by that experience, they now intended to convey wires from every furnace in the place, twelve in number, at varying distances from the point of observation. They intended to have a series of wires, not only giving the temperature of the blast itself, but, what was also a very important matter, the temperature of the escaping gases. He sincerely congratulated the son of his old esteemed friend, M. le Chatelier, on having been the means of supplying what appeared to be a trustworthy instrument, and he was grateful to his friend, Professor Roberts-Austen, for having drawn his attention to it.

The PRESIDENT said he had had the great advantage of seeing Professor Roberts-Austen carrying out experiments with his method of recording the indications of the pyrometer, and he could thoroughly endorse everything that Sir Lowthian Bell had said with regard to the sharpness and accuracy of the indications obtained, and with respect to the great promise of this method of measuring temperatures as a practical means of rapidly and exactly ascertaining what they wanted to know with regard to the temperatures of furnaces and escaping gases, and to the course of metallurgic operations. The fact that observations of this class could be made at considerable distances from the scene of operation, as Sir Lowthian Bell had pointed out, was a most important element in connection with the practical application of the method. If any gentleman desired to ask a question on the subject, no doubt Professor Roberts-Austen would be pleased to reply.

Mr. J. E. STEAD said he wished to ask Professor Roberts-Austen how the junction was put into contact with the molten metals without causing an alloy to take place? Everything had

been explained very clearly except that point. He had not had the pleasure of seeing the apparatus at work, and he thought it would be of interest to know how the junction was put into contact with or in the presence of molten metals at high temperatures without the alloying. Of course there must be some protection to prevent that.

The PRESIDENT asked M. Le Chatelier to be kind enough to give some observations with regard to the method of calibration.

Mr. CHARLES WOOD said he wished to ask Sir Lowthian Bell whether he had one of the instruments in use?

Sir LOWTHIAN BELL said that he had, and that Mr. Wood was at liberty to see it whenever he chose to apply.

Mr. WOOD asked if Sir Lowthian Bell proposed, when the wires were placed in the gases or hot blast, to let them remain there?

Sir LOWTHIAN BELL said that that was the case.

Mr. WOOD said in that case there were one or two things that he thought would occur. The wires would soon become covered with gas deposits, which, to his mind, would have certain results upon the recorded temperatures. All the pyrometers they had in use were more or less affected in that way. On the other hand, supposing they were placed in the high temperatures of blast, which sometimes, according to Siemens pyrometers, ran up to 1700°—he had seen it even higher than that—then a certain amount of oxidation or change in the metallic wires would take place, if the wires remained constantly in the blast. Many years ago a pyrometer with platinum wires was introduced into Cleveland, and he believed that a similar action did take place, and that the constant remaining of the wires in those high temperatures materially affected the recording of the proper temperatures, and he could not help thinking that if the wires were to remain either in the gases or in the heats, although, when they were first set to work, they might give a very good result, they could not

be depended upon even after a few days' work. He had seen great changes in pyrometers taking place; even with copper balls they could not be depended upon for more than a week or two; and if they were kept in longer use than that the difference in temperature recorded was very considerable, and he imagined that the instrument described would suffer in a similar way. Another point was that they wanted something handy which one man could take about to the furnaces in his hand, and he was afraid, by the appearance of the instrument, that if the drawings of the one shown was of the actual size, it would be a very inconvenient thing for daily use. It might be very well in the drawing-office as a standard, but he thought it would not be of much use to take round to the furnaces two or three times a day.

Sir LOWTHIAN BELL said that they had not had sufficient experience to know whether the wires would become altered, in the way referred to by Mr. Wood, by a continued exposure to high temperatures. With regard to incrustation by the deposit of flue dust, that might take place, but he hoped to a very limited extent; and if such was the case he did not apprehend in it any serious difficulty. But he should like to hear what Professor Roberts-Austen had to say upon this subject.

Professor ROBERTS-AUSTEN said that the question of the protection of the pyrometric couple was a very important one. It appeared to be a matter of absolute indifference in the case of gold and palladium whether the wire was protected from their action or not. They might plunge the wire into molten gold or palladium, and get the full effect of thermo-junction. It appeared, therefore, to be a matter of perfect indifference whether the junction was protected or not in cases where the alloying metal did not creep up the wires and alloy with them. It was a different question in the case of a volatile metal like zinc, where some means of protection must be adopted. Grinding down a tobacco-pipe, and placing the junction in the bore, or covering the wires with a cap of platinum, answered perfectly. But, for extended observations, Messrs. Morgan, of Battersea, made a specially-constructed crucible, with a tubular orifice in its base, into which tubulure the thermo-couple was inserted. The only objection was, that there was a little lag

by the transmission of heat from the molten metal through the tube, but as all measurements were relative, it did no harm. He had found that method an admirable one for observation, not so much for determining the melting point as the rates of cooling the metals and alloys. There was no fear, so far as he knew, of the oxidation of platinum, but it should be noted that a carbide did appear to form. The wires did become destroyed if the carbon acted upon them, but it was easy to protect them by porcelain, which would preserve them indefinitely, at any rate at temperatures which it was usually necessary to measure in iron works. Sir Lowthian Bell had pointed out that, taking as a known temperature the melting point of zinc, and plotting it, his (Professor Roberts-Austen's) experiment did not go through it. The pyrometer readings of the results were unsatisfactory. That was true, but zinc was one of the worst metals they could have, because it acted on the thermo-junction. He agreed with M. Le Chatelier in thinking that there was an uncertainty of at least 50° in the case of palladium, and 25° in the case of gold. All that he could say was, that when those known temperatures were taken and the indications of the pyrometer were recorded, the line of the curve went through at least two determinations of gold, and near the second determination of palladium. They might have shifted gold up to 25° more, and that would bring palladium 50° higher, and the curve would still be a continuous one; but for all purposes of reference the results were sufficiently accurate. When it was a question of measuring temperatures of 2000° they need not cavil at a difference of 25° in the present state of our knowledge as to pyrometric measurement.

The PRESIDENT said that the Institute was extremely indebted to Professor Roberts-Austen, not only for bringing his valuable method of working to their notice, but also for devoting his energies to facilitating the use of the Le Chatelier pyrometer, so as to put it at the disposal of every practical man, and for calling their attention to his results in so lucid and satisfactory a manner. He would ask the members to pass a cordial vote of thanks to Professor Roberts-Austen for his communication.

A vote of thanks was given by acclamation.

CORRESPONDENCE.

Mr. OSMOND (Paris) thinks that the scientific interest of the process employed by Professor Roberts-Austen for automatically registering the curves of cooling is self-evident, and that the perfection of the curves obtained sufficiently proves that the installation has been well thought out. He would merely like to point out the practical interest for the metallurgical industry that would be presented by the application of this method.

The curve of cooling of a steel is, in the majority of cases, characteristic of its chemical composition. If, for example, carbon and manganese are the only independent variables, and if the other foreign elements are present in negligable quantities, or merely in constant amounts, the amplitude and the position of the critical points give the proportion of carbon and of manganese quite as well as analysis does, provided that the initial temperature and the velocity of cooling are the same in the experiments under comparison.

The requisite conditions are frequently attained in the manufacture of acid open-hearth steel, and by taking the curve of cooling of test-pieces, an operation may be stopped with the greatest certainty.

This conclusion will perhaps be received by practical men with surprise. It is clear, however, that the installation arranged by Professor Roberts-Austen could not be transported just as it is to a metallurgical works. But, with the modifications and simplifications demanded by the necessities of the industry, it does not appear impossible to obtain good curves at the furnace in the space of a few minutes. Mr. Osmond, who has filled the post of engineer to steel-works, would not hesitate, if he should again be required to manage open-hearth furnaces, to make the experiment.

The following paper was submitted by Professor Roberts-Austen, C.B., on behalf of the Author :—

NOTE ON THE MICRO-STRUCTURE OF STEEL.

BY F. OSMOND, PARIS.

IN presenting to the Iron and Steel Institute a series of micro-photographs, which were exhibited last year at the Mining Exhibition held at the Crystal Palace, I do not pretend to offer a completed work. Notwithstanding the admirable researches of Dr. Sorby, which indicated the path and fixed the method of investigation, the structure of steel is so complex, and its study is so delicate, that the question is far from being exhausted. I shall therefore merely endeavour to give an idea of the present state of my researches, and of the points of practical interest which they present.

In examining the micro-photographs, special attention need not be paid to those that have been made with oblique illumination; although they supply an amount of information that is often of value, at the same time they sometimes give an incorrect idea of the structure. The photographs taken with normal illumination by Beck's vertical illuminator are usually clearer, and I shall confine my attention to these.

Very mild steel is formed of polyhedral grains of almost pure iron, in each of which the iron presents a crystalline orientation, which is constant for the same grain, but which varies in the different grains. The grains of iron appear to be surrounded by foreign matter, carbide of iron. As the temperature is raised, the grains at first increase in size without changing their form; then they become elongated, and form a group of parallel bands.

In steel of medium hardness the white portions consist of almost pure iron, and the dark portions consist of a mixture of iron and of carbide, the "pearly constituent" of Dr. Sorby. In metal properly heated and well worked, the pure iron forms torn-up and discontinuous stripes; but when the temperature is raised, the formation of polyhedral grains becomes more and more

evident, until the pure iron completely envelops these grains, and grows into them under the shape of fine parallel bands.

In hard steel the pure iron behaves in a somewhat similar manner, but it is, of course, of much less frequent occurrence. I succeeded in obtaining for this metal a photograph which shows, when magnified 300 diameters, the alternately dark and brilliant striæ discovered by Dr. Sorby, and considered by him to be alternate lamellæ of iron and carbide of iron.

Independently of any theoretical interpretation, one fact is clearly indicated by the photographs. This is that each preparation defines not only the hardness of the metal, other things being equal, but also the temperature at which the metal was allowed to slowly cool. Moreover, as the structure and the mechanical properties are intimately associated, it can easily be imagined, without making it necessary to enter into fuller details, to what extent microscopic investigations may furnish useful information, whether as to the value of a given metal, or as to the mode of correcting, and of controlling, the working.

The paper was illustrated by a series of photographs, from which Plates I. to VIII. have been prepared.

Professor ROBERTS-AUSTEN, C.B., F.R.S., said that M. Osmond followed the method of Dr. Sorby accurately, and recognised the great merits of Dr. Sorby's work. The main point was that in the previous determination of the micro-structure of steel the temperature to which the metal was subjected had not been accurately measured. In the specimens exhibited by M. Osmond at the Metallurgical Exhibition at the Crystal Palace last year, such accurate pyrometric measurements by the instrument which M. Le Chatelier had given them, were made before the metal was sliced and submitted to inspection by the microscope.

The PRESIDENT said that members would remember that he had dwelt at some length upon the method of examining iron and steel referred to in the paper. It had been in use in different ways for a great many years, and had been developed to a

considerable extent of late, and there could be no doubt that if further experience was obtained in its employment, they would be enabled to acquire very valuable information by its means in regard to the quality and nature of the products, and in regard to many points of considerable importance connected with the production and treatment of steel. The members were greatly obliged to M. Osmond for his communication, and for the exhibition of the photographs.

ON THE CHANGES IN IRON PRODUCED BY THERMAL TREATMENT.

II.

BY E. J. BALL, PH.D., LONDON.

IN a paper "on the changes in iron produced by thermal treatment,"* read last year before this Institute, at the request of Professor Roberts-Austen, I published the results of some experiments made a few years ago, which showed that in addition to the three points of change which have been observed by Osmond, there appears in very mild steel to be a fourth point, which occurs at a temperature approaching the melting-point of the metal itself; and I further showed that this point of change coincides with the point of maximum tenacity.

In the discussion which ensued on the reading of the paper, it was observed by M. Osmond that the change which took place at this high temperature might have been due to the fusion of iron oxide adhering to the metal, the fusion of this scale affecting the subsequent. Admitting the possibility of this, other experiments were made in a similar manner, but under strongly reducing conditions, and as the results seemed to show that the suggestion as to the effect being due to oxide could not be correct, the experiments have been continued. The results thus far obtained are not without importance, as they show: (1.) That in iron containing 0·1 of carbon, the tenacity of the metal increases by hardening either in oil or in water, with the temperature at which the metal is quenched with a view to hardening, a maximum tensile strength being reached at a temperature of about 1300° C. This temperature once exceeded, however, the tenacity of the metal diminishes, although the extensibility increases. (2.) By raising the percentage of carbon from 0·1 to 0·2, the curve representing the tensile strength shows a maximum point at about the temperature of 1000°—below the melting-point of iron

* *Journal of the Iron and Steel Institute*, 1890, No. I. p. 85.

oxide, which, moreover, was not present. (3.) By further considerably increasing the percentage of carbon, this point of maximum tenacity apparently disappears almost entirely, the annealed metal having nearly as high a tensile strength as the same metal which has been quenched in oil from any temperature up to a bright red heat. Beyond this temperature, or when quenched in water, the hardened metal became so hard and brittle that it could not be gripped by the jaws of the testing-machine.

Whilst, however, the tenacity of the high carbon steel was not greatly influenced by quenching, both the hardness and the brittleness of the steel increased with the initial temperature of the metal before quenching, until at the initial temperature of about 1400° C., obtained by heating the metal in a crucible in a wind-furnace, the iron had become so brittle that there was very little resistance to shock at all, either when hot or after hardening. The metal, even if cooled gradually in a muffle from this temperature, was also extremely brittle.

It should be observed that this temperature of 1400° was that of the incipient fusion of the steel.

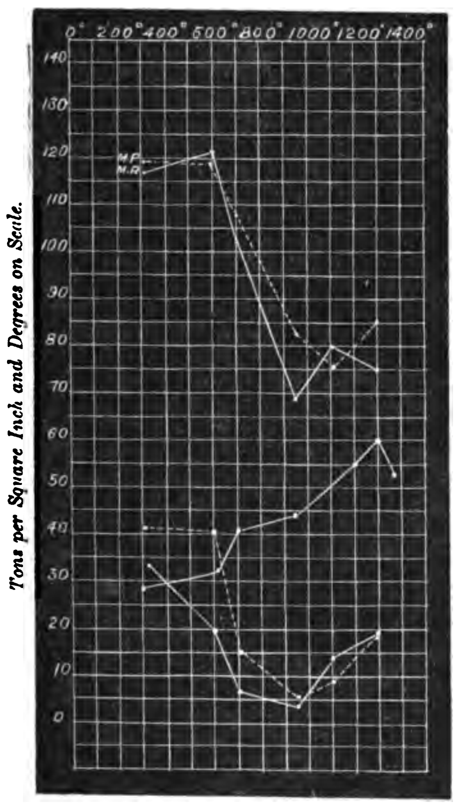
The tenacity of iron would appear not to be directly connected with its degree of either hardness or brittleness. Neither is this change in the mechanical properties of the metal at high temperatures due to a "carbon change," for it is most pronounced when carbon is almost absent, the introduction of increasing percentages of carbon apparently having the effect of producing a gradual diminution in the temperature at which the change takes place. The change is not due to oxide. Is it an "iron" change? Is it due to a form of iron existing when left to itself only at temperatures approaching the melting-point of the metal, but rendered stable at lower temperatures by hardening or by the presence of carbon?

Very probably other elements besides carbon have a similar effect, but in these experiments an endeavour has been made to render the results comparable by using steels of approximately the same composition, with the exception of the carbon. The following are analyses of the milder steels used:—

Steel.	C.	Mn.	Si.	S.	P.
1. . .	0·13	0·284	0·004	0·069	trace.
2. . .	0·12	0·546	0·011	0·089	trace.
3. . .	0·25	0·350	0·012	0·160	absent.

The curves of magnetic permeability of Nos. 1 and 2 were published in the original paper, but as these results might, to some extent, have been influenced by the presence of temporary internal strains resulting from the hardening, two other series of bars of the Bessemer metal were hardened in oil and in water, placed vertically in a glass jar, and allowed to remain for a year before submitting them to examination by the Hughes' magnetic balance. The results are shown in fig. 1, and are quite concordant with

FIG. 1.—TEMPERATURES.



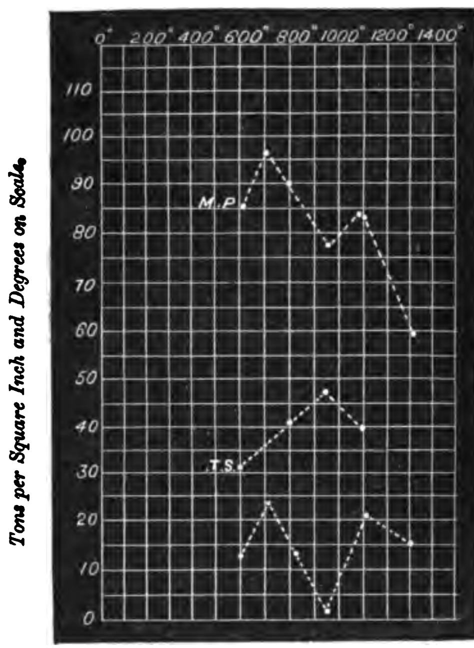
those previously exhibited, except that the hardened bars, under the influence of the earth's magnetism, had become more strongly magnetic, with the result that the curves representing their direct

repellant action on the magnetic needle of the balance are much more regular, and the salient points more pronounced.

The dotted lines represent the bars hardened in oil, the others showing those hardened in water. The tensile test-curve is marked T.S., and is that published last year for the other bars. There are probably unobserved maxima existing between the two higher points of the curves of magnetic permeability.

The other steels were examined in the same manner as that described in the previous paper, but using a reducing atmosphere. Fig. 2 gives the curves obtained with the steel containing 0·2 per cent. of carbon :—

FIG. 2.—TEMPERATURES.

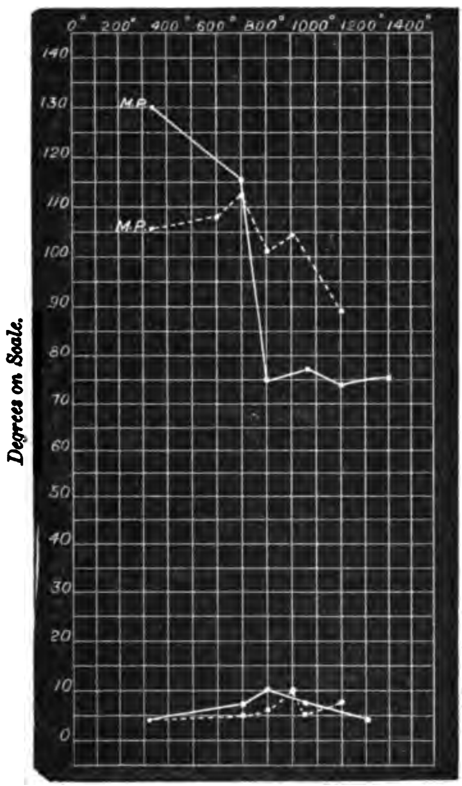


These curves show (M.P.) the magnetic permeability of the bar hardened in oil, its tensile strength (T.S.), and its direct repellant action on the needle of the balance. This steel was in the form of a round rod 0·133 inch in diameter. Hardened in water, the maximum strength was 75·3 tons, this strength being attained at

the same temperature as in the case of the oil-hardened bars, and diminished again rapidly at higher temperatures.

Fig. 3 gives similar results as obtained with the high carbon rod. This had a diameter of 0·231 inch.

FIG 3.—TEMPERATURES.



I have endeavoured in these later experiments to meet the objection of M. Osmond, that the change observed in very mild steel at about 1300° is due to the formation and fusion of iron oxide. The experiments which are now described were conducted under conditions which prevented the formation of oxide, and while the bars, in the earlier experiments criticised by M. Osmond, showed scale, they were now free from it. Again, in the 0·2 steel, the maximum tensile strength was reached below the melting-

point of the oxide, even had it been formed, which was not the case.

M. Osmond further suggests that the change is closely connected with the structure of the metal. This seems not at all improbable. It does not appear, however, to be directly connected with a change in the mode of association of the carbon, as the carbon changes have taken place long before the maximum tenacity has been reached in mild steel. Neither does it appear to be due to the sudden development of crystallisation observed by Brinell, for if this were the case, instead of a gradual rise in the tensile strength to a maximum, followed by a gradual fall, accompanied, at least at first, by increased extensibility, a sudden and considerable diminution in the tenacity and extensibility might be expected.

Whether this increased tensile strength is entirely or only partly a direct consequence of the strains produced in the metal by the act of quenching is again an open question, but it seems evident that by quenching from a high temperature a change of some kind is produced in the iron under treatment, and that the extent of this change is dependent on the temperature and on the chemical composition of the metal.

In view of the abnormal results obtained on hardening the high carbon steel previously referred to, I hesitate to publish details, preferring to reserve this question to a later date, when I hope to be in a position to give the results of other and more complete experiments which are now in progress.

[*June* 23, 1891.—Since this paper was read, other experiments have afforded evidence that in the case of the 0·2 steel the tensile strength increases, as stated in the paper, to a maximum at the temperature of about 1000°, diminishing again for the next 100° or 200°; but that beyond this point, instead of a continuous fall, there is a second and exceedingly rapid increase, a tensile strength of 110 tons per square inch being attained in the case of the bars hardened in water at the maximum temperature of the experiments. It would appear, too, that the specific heat of the metal increases with the temperature of hardening up to a point at which a maximum is attained, a further increase in the temperature producing a diminution, instead of an increase, in the specific heat.—E. J. B.]

DISCUSSION.

Mr. Thos. Wrightson said that he had read the paper with very great interest, because he thought he recognised in the critical point which the author had investigated the same critical point which he (Mr. Wrightson) had ascertained some years ago in the course of experiments which he made upon the changes of volume in cast iron at high temperatures. At that time he was enabled to show the change in volume by submerging 4-inch cast iron balls in a bath of liquid cast iron. By suspending these balls upon a spring, he found means of measuring the flotation, which varied according to the expansion of the ball. By applying a recording apparatus to the spring he was enabled to form a curve which showed the change in volume that was going on underneath the surface of the metal. Without saying more about the instrument which was used for that purpose, and which was fully described in the papers to which he had referred,* he would show the form of diagram which his instrument produced.

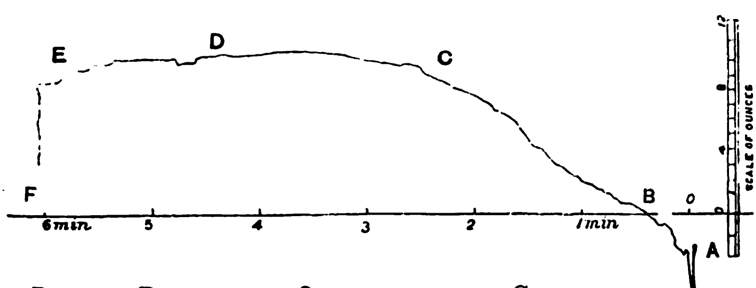


Diagram Produced by Oncosimeter with Calculations of Density for Cast Iron.

4-inch ball of foundry 4, Cleveland. Run with very hot metal. Immersed in No. 4 foundry.

Date of Experiment, 25th April 1880.

Weight of ball and immersed part of stalk	. . . .	132 oz.
Specific gravity of ball and immersed part of stalk	. . .	6·95
Maximum sinking effect	. . . .	2 ,,
Maximum floating effect	. . . .	11 ,,
Specific gravity of fluid iron	$= \dfrac{6{\cdot}95 \times 130{\cdot}0}{132}$	$= 6{\cdot}84$
Specific gravity of plastic metal	$= \dfrac{6{\cdot}95 \times 130}{143}$	$= 6{\cdot}32$

* *Journal of the Iron and Steel Institute*, 1879 and 1880.

The vertical ordinates represent weight in terms of the changing buoyancy of the submerged ball, which, according to the law of floating bodies, is equal to the change in displacement or volume. This is registered by a pencil attached to the free end of the spring. The horizontal base-line gives the element of time, and the paper on which it is registered is wound round a cylinder actuated by clock-work.

This base-line coincides with the zero of the vertical scale of weight, so that when the pencil is crossing this line the ball is exactly of the same density as the liquid metal.

When the ball was first put into the metal it had a sinking effect, which was shown upon the diagram by the depth of A below the base-line, viz., 2 oz. in this particular case (the zig-zag line below A is due to an unavoidable oscillation of the spring as the operation commenced). As the heat entered the ball, expansion took place, and the instrument recorded the line as rising and passing the point B, which represented the density of the liquid iron. Therefore, at the point when this part of the diagram was being formed, it showed that the solid ball was exactly of the same average density as the liquid iron. As the expansion continued, the line kept rising towards C, which point it reached in two and a half minutes, and then very gradually to D, the point of maximum volume, which it reached in four minutes, and registered 11 oz. increase of buoyancy. Here it was evidently in a plastic state. He ascertained that this was the case, by drawing a great many of the balls in his experiments from the bath of iron at this stage; and so perfect was the conduction of the heat into the iron balls that they still retained their circular form, and yet were so plastic that he could push a piece of small wire through and through. From the point D the line droops to E, where the iron was evidently near the point of liquefaction. At this point there was a very rapid fall in all the diagrams taken, which indicated that the ball was turned into liquid rapidly. Of course, as soon as it really melted and joined the mass of liquid in the vessel, it became of the liquid density. Therefore in the diagram there was a clear indication of what occurred in the cast iron in passing from its cold state through the intermediate stages of temperature to the liquid state. He found that the diagram

always descended quickly at E, indicating that the change from the plastic to the liquid state was rapid. The slight fall from D to E was probably due to a small reduction in the mass of the ball by melting. The iron in the ball therefore appears to pass through three different conditions, so far as the effect of heat upon volume is concerned. From A to C the iron had the property of *expanding* by heat. From C to D, and probably to E, the increasing heat had no practical effect on the volume, and from E to F the material *contracted* by the addition of heat.

No doubt, from what had been observed as to the floating of steel in a bath of steel, the diagram of a steel ball would have similar, though probably not identical, characteristics. The critical point E, when iron suddenly begins to contract with an accession of heat, corresponds, he believed, to the critical point of Dr. Ball, who pointed out that it was within a few degrees of melting. His (Mr. Wrightson's) critical point C probably corresponded with one of the critical points of M. Osmond. He had no doubt that the change which took place in the volume (he only professed to have investigated the critical point as expressed in volume) would be indicated in other ways; in all probability, the electrical conductivity might change in some way, and the tensile strain of the material which was quenched at or near the critical point might also differ. He regarded Dr. Ball's paper with the greatest interest, because he saw that the quenching of the steel at that critical point, or after it had just passed it, when the material was endowed with different properties so far as the effect of heat upon volume was concerned, might in all probability explain the extraordinary differences found in the strength and other properties of steel when quenched at those temperatures. He had very little doubt that if they could get diagrams of the behaviour of steel in the same way that he had obtained diagrams of the behaviour of cast iron, very great light would be thrown upon this most interesting subject.

Sir LOWTHIAN BELL, Bart., said he should like to say a word or two with regard to the cooled metal he had immersed in cast iron. It was so little heated that merely the edges of it were red-hot. On breaking the cube through the metal it was found to be of a dull cherry red in daylight; there was no approach at

all to the temperature described by Mr. Wrightson, and it had therefore occurred to him whether there might not be something in treating a cold mass like that which did not obtain in Mr. Wrightson's diagram—a diagram, by the way, that corresponded very nearly with his own. He supposed, when the mass of iron sank to the bottom, that the occluded gas in the cast iron itself might possibly be liberated by the consolidation of the iron next to the cold mass that he put in; and in that way there would be, as it were, a film of gaseous matter interposed between the cutting of the solidified iron in the bath, which possibly might tend to lift the end up. There was a very small margin between the sinking and the floating; and, on examining the iron, to the best of his recollection, there were grounds for supposing that it would have been possible. It was quite certain that, in the several trials he had made of the cubes of iron, so treated, they sank to the bottom, and remained there about thirty or forty seconds, and then rose to the top, where they remained.

Professor Roberts-Austen said that the allotropic form of iron had been recognised as being a vital one. He did not know whether M. le Chatelier would agree to the accuracy of the view that as the iron cooled down and attained a temperature of 855° Cent. it did undergo molecular change. As steel of average composition cooled down, there was another evolution of heat when the temperature of the mass fell to 645° or 650°. This change was one in the relations between the carbon and the iron; so that they had these two critical points 855° Cent. and, say, 650° Cent. If Dr. Ball's observations were pursued to their logical conclusion, he thought they would have to admit another allotropic change at 1400°. That was a very serious thing. Many people found it difficult enough to recognise that iron could change its nature at one temperature, but to admit that it could change twice was more serious, as M. Osmond had already shown that the position of the first point varied with the degree of carburisation. M. Osmond had written a letter that morning to the effect that the change observed by Dr. Ball was in some way connected with, and is a part of the molecular change occurring at 850°, and was not a distinct change itself; and it should be remembered that M. Osmond had already shown that the critical point at 855° varied

with the degree of carburisation of the mass. It was, however, impossible to make these points clear without the aid of the diagrams which were shown at the last annual meeting.

Mr. G. J. SNELUS said he thought the intricate changes in the condition of iron were very interesting, but they were extremely difficult to follow. There was one condition of matter, however, which he ventured to think they had overlooked in those changes, viz., the crystalline condition. Any one who had ever seen a broken railway axle, and the very large facets that appeared in the iron, which at one time no doubt was fibrous, would know that vibration had an enormous effect in producing crystallisation. He thought that the change of temperature had the same result; in fact, the experiments to which he had previously alluded had convinced him of the enormous effect of crystallisation in inducing changes in metal. He had already mentioned that in treating an alloy of iron and zinc by pouring molten metal, which was thoroughly homogeneous, into an iron mould, crystallisation had separated the mass into two different compounds, one of which contained twice as much iron as the other. In that experiment he found it almost absolutely impossible to stop crystallisation. He had found, to his astonishment, that the segregation was assisted by rapid cooling. In the case of large masses of steel they knew that segregation of the metalloids was assisted by slow cooling. Those elements which separated from the mass were known to go to the centre of the ingot which remained fluid longest. In his innocence, in carrying on these experiments, and in endeavouring to get a perfectly homogeneous body, he thought he should get it by casting the metal into a cool mould and rapidly chilling it; but, to his astonishment, crystallisation came into play, and instead of getting homogeneity he got the exact reverse. He found that in order to get a homogeneous mass in that case he had to revert to the very opposite thing, and adopt slow cooling. By extremely slow cooling he stopped crystallisation, and got a more homogeneous mass. He thought that crystallisation might have a great deal to do with the results which had been noticed in those thermal investigations, and he would venture to suggest that some attention should be paid to that particular line of investigation. It was quite clear that the

tensile strain of a metal must vary immensely according to the direction in which the cleavage planes were set up by crystallisation. Everybody knew that if carbonate of lime in its crystalline form was just touched with a penknife in one direction its planes would cleave asunder with the greatest ease, but if it were touched across the planes of cleavage it would be found to be very tough indeed. Knowing, as they did, the wonderful power of crystallisation of iron and steel, he thought they must look to it for some of the anomalies of which they had heard. They might find that the anomalies had been due, perhaps, to crystallisation more than to a change in the allotropic form of the iron. At all events, he thought that that was the direction in which investigation should be carried out, and perhaps it would throw some light upon the changes noticed in iron, and upon some of the failures which had hitherto been quite inexplicable.

Mr. R. A. HADFIELD said he should not have ventured to speak on Dr. Ball's paper respecting temperature effects on iron had it not been that quite recently he had made one or two experiments with reference to the condition of iron—that is, pure iron. It seemed to him that the question of temperature effects upon this metal was a most important one, and that it had not been hitherto pushed as it might have been. The papers, although modest in size, related to very important results. It seemed to him that the best way of determining the effect of the cooling of iron would be to get a sample as nearly pure iron as possible, and he was able to obtain some bars containing 99·8 per cent. with a trace of carbon, or as nearly pure as one could expect to obtain in commercial specimens. The material was supplied by Mr. T. W. Sorby of Sheffield, and kindly tested for him by Professor Ripper, the Principal of the Sheffield Technical School, the results being as stated in the table that follows. In order to see fully the effect of quenching, the samples were prepared in very small sections, so that in cooling from a high heat the full force of the quick reduction in temperature could be obtained.

For convenience of comparison the tests in the table are given in the order of their tensile strength:—

Sample No.	Treatment.	Tensile strength in tons.
		Per sq. inch.
7	Heated to yellow heat, quenched in water (60° F.), and reheated to yellow heat .	17·90
4	Welding heat, cooled in air . . .	19·05
8	Yellow heat, cooled in water, and reheated to low red	20·82
5	Yellow heat, and cooled in air . .	20·94
3	Low red, and quenched in water . .	21·22
2	Yellow, and quenched in water . .	21·28
1	Welding, and quenched in water . .	21·55
6	Tested just as forged, evidently "hammer-hardened"	22·58

All the specimens were heated in an ordinary smith's fire, and the water used for quenching was 60° F. Nos. 7 and 1 samples were heated to about the same temperature, and Mr. Hadfield calls special attention to the effect of the reheating (after water-quenching) in sample No. 7.

The results showed that No. 6, tested just as forged, possessed even higher tensile strength than the water-quenched specimens, probably being slightly "hammer-hardened." Even the water-quenched specimen, quenched from a welding heat, except for a very slight surface skin-hardening (as suggested by Mr. Stead, this would probably be from a slight absorption of carbon from the fuel), could be easily filed, and apparently no change to a hard condition of the iron had taken place. This, of course, in no way militated against M. Osmond's hypothesis that iron, when in combination with other elements, such as carbon, might assume another form. All that was wished to be now proved by Mr. Hadfield was that a sudden cooling of iron, or practically pure iron, did not produce any material change in hardness. This had been independently proved by Mr. T. Andrews in his excellent paper, "The Impact Resistance of Metals," contributed to the Institution of Civil Engineers. His experiments were made to determine the effect of sudden cooling on wrought-iron axles, produced by him at his Wortley Forge. The average tensile strength of some twelve samples of the iron tested (their analysis showed 99·43 per cent. Fe., but also ·13 per cent. Si., ·17 per cent. P., and ·23 per cent. Mn.), in its untreated state, was 21·65 tons per square inch. The same material, quenched

from a white heat (2786° F. actually determined) to 32° F., only increased about 1 ton in tensile strength, viz., to 22·53 tons.

To Mr. Hadfield it seemed that Dr. Ball in his paper had suggested the true cause of any increase in tensile strength by water-quenching mild steel or wrought iron, viz., "that although an open question, it may be wholly or partly the direct consequence of the strain produced in the metal by the act of quenching." Dr. Ball mentioned that he had fuller and further experiments in hand. They would be waited with much interest.

In conclusion, he hoped that Professor Roberts-Austen would also continue his investigations with the excellent apparatus that he had completed. The best thanks of the Institute were due to him, as well as to Dr. Ball and M. Osmond, for the important research work they were carrying on.

Professor Roberts-Austen said he claimed the facts mentioned by Mr. Hadfield as part of his case. M. Osmond had clearly shown that iron, when cooled, did not retain the β, or hard molecular, grouping unless a certain amount of carbon was present. It was the presence of carbon that prevented the change of β to α iron when the mass is rapidly cooled by quenching from bright redness.

The President said he thought that was so.

Professor Roberts-Austen therefore claimed the fact mentioned by Mr. Hadfield as part of his case. He ventured to think that Mr. Hadfield's own beautiful alloy of manganese and iron which did not harden by slow cooling, and in which the iron was presumably in a β state, proved M. Osmond's case as to the allotropy of iron. He admitted that at first sight it was disappointing that they could not isolate iron in the β state, but they did not yet know all the necessary conditions, and facts of the utmost importance in molecular chemistry were being rapidly gathered.

The President said that the interesting discussion on Dr. Ball's paper clearly showed the vast amount of patient work that must still be bestowed on this important subject. He confessed

he thought that, on the face of it, M. Osmond had made out a very good case for the allotropic or β form of iron, and he thought that Professor Roberts-Austen's last point was a correct one, that the presence of carbon was essential in the production of the hardening effect. It was, however, important to know that others besides Mr. Hadfield considered that much remained to be accomplished in the study of this subject. Dr. Ball himself had said that he brought forward those results with some hesitation, and mainly with a view to provoke discussion, and that he hoped to elaborate the subject still further. The members would, therefore, look for the pleasure of again hearing from him; at any rate, they were much obliged to him for the instalment of his results which he had kindly given. It was very important that, as results were obtained, they should be published in order that those who were working at the same subject might reap the advantage of knowledge already acquired, and become aware of the difficulties which had still to be met. They were much indebted to Dr. Ball, and he would ask the members to thank him for his paper.

CORRESPONDENCE.

Mr. F. Osmond has offered the following remarks:—In the discussion of Dr. Ball's first communication (1890, p. 102), I expressed the opinion that the facts observed by the author might be due, at least to a certain extent, to the presence of ferric oxide, and to the fusion of this oxide at 1300° C.

Although this suggestion was not confirmed by experiment, I do not regret having proposed it, since it has led Dr. Ball to repeat his experiments under more simple conditions, and to make new and interesting observations. It is therefore now proved that the coincidence of Ball's point and the fusion of ferric oxide in very mild steels is merely fortuitous.

There remained, however, two factors that may intervene, separately or together:—

(1) The changes in the structure with the temperature; and

(2) The known molecular changes of the iron.

With reference to the changes in the structure, I should like to direct Dr. Ball's attention to the photographs that I exhibited at this meeting. These photographs do not offer a solution of the question, but they give an idea of the part that may be played by structure in the mechanical properties of steel.

With reference to the molecular changes of the iron, the results obtained by Dr. Ball, that is to say, the lowering of Ball's point in inverse ratio to the proportion of carbon, suggests the idea that the new point may be referred to the known point a_{c3}. The change of the a-iron into β-iron during the heating may, in fact, be progressive, and present, as Dr. Ball himself remarked in his first paper, the character of a dissociation. What gives some probability to this hypothesis is the fact that the quantity of heat absorbed at a_3 during the heating seems always to be much less than the quantity liberated during the cooling. As, however, the two quantities are obviously equal, we are led to believe that the molecular change during the heating is distributed over an interval of temperature more or less extensive. Further experiment alone can elucidate these delicate questions.

ECONOMICAL PUDDLING AND PUDDLING CINDER.

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In 1784, or a hundred and seven years ago, Cort invented the puddling process, and thus laid the foundation of much of the prosperity of this country during the century which followed. The present importance and vitality of the industry is shown by the remarkable fact that, despite the wonderfully simple method invented by Bessemer, and the beautifully perfect furnace of Siemens, it has required thirty-five years of sharp competition to render the weight of Bessemer ingots annually produced in this country equal to that of the puddled bar manufactured by the old process. This vitality is due in great measure to the fact that for certain purposes the characteristic properties of wrought iron render it preferable to mild steel, and is doubtless also in part due to the circumstance that in many cases capital has been invested in an ironworks, and cannot now be easily realised or converted into more modern plant. At all events, the success of the puddling process can scarcely be due to the interest which ironmasters have in the past taken in the more theoretical or scientific aspect of their business, for we find, on examining the literature of the subject in this country, that, with the notable exception of Mr. Henry Kirk of Workington, one of the original members of the Institute, the contributors have been almost without exception either professional chemists or teachers, and may, therefore, like the writer of this paper, be considered amateurs.

For our knowledge of the manufacture of cast iron and steel, on the other hand, we depend largely on the work of men connected with the particular branch they studied, and it is somewhat characteristic that the best known, and probably the first systematic investigation of the changes which take place during puddling was made a year after the Bessemer process was introduced. Even at

the present day, despite the fact that this Institute has been in existence over twenty years, there are to be found those who successfully conduct ironworks, and yet have no more understanding of the theory of the process than had Cort himself a century ago.

This apparent want of interest shown by the practical man in the scientific aspects of puddling is probably due in part to the knowledge that the information generally supplied is either incomplete, and not quite what is wanted, or that it is actually incorrect, and consequently misleading. As an example of the first, we are commonly informed that the impurities of the pig iron are oxidised by the oxide of iron present in the fettling, and such an explanation, when it is added that the carbon passes off as gas, while the silicon, phosphorus, and manganese remain as oxides in the slag, is generally considered sufficient.

To this it may reasonably be objected that it is very doubtful whether it is possible successfully to puddle a tolerably pure pig with pure ferric oxide alone. It would, at all events, certainly lead to waste of time and metal in the early stages of the process, owing to a deficiency of fusible cinder, would probably lead to thick slag and inferior iron at the end of the process, and would also be very liable to cause the bottom to scurf. These facts show the importance of a due proportion of silica, ferrous oxide, and phosphoric anhydride in puddling cinder in order to ensure the requisite fluidity, a point which is seldom referred to in explanations of the process. But further information is also necessary as to the manner in which the oxide of iron present in the furnace acts upon the impurities of the iron. Thus, if we consider, for simplicity only, the case of carbon, a number of actions are possible such as—

$$\left.\begin{array}{ll}(1.) & Fe_2O_3 + 3\,C = Fe_2 + 3\,CO \\ (2.) & Fe_2O_3 + C = 2\,FeO + CO\end{array}\right\}\text{With ferric oxide.}$$

$$\left.\begin{array}{ll}(3.) & Fe_3O_4 + 4\,C = Fe_3 + 4\,CO \\ (4.) & Fe_3O_4 + C = 3\,FeO + CO\end{array}\right\}\text{With magnetic oxide.}$$

$$(5.)\ FeO + C = Fe + CO \quad \text{With ferrous oxide.}$$

If 12 parts by weight of carbon be taken as a standard for comparison, and the above equations are arranged in the order of iron reduced and fettling used, we have the following values:—

Equation.	Iron Reduced.	Fettling Used.
(5.)	56	72
(3.)	42	58
(1.)	37	53
(2.)	0	160
(4.)	0	232

Hence, taking the two extremes, according to equation (5), 1 lb. of carbon would reduce 4⅔ lbs. of iron, and use 6 lbs. of fettling; while, according to equation (4), 1 lb. of carbon would reduce no iron, but use 19⅓ lbs. of fettling; yet a well-known Cleveland chemist uses equation (5) to explain the removal of carbon, while the author of a recently issued text-book explains the action according to (4).

Now the most important reaction for the removal of carbon may be some one of the five above represented, or the process may be the result of several, or of all of them together. Again, the reaction by which carbon is removed may be of one kind, and that by which phosphorus is eliminated may be of another, and thus a whole range of possibilities is opened up to view, on which, so far as I am aware, no definite information is at present attainable. And yet these questions are of the greatest practical importance, as their solution would enable us to theoretically predict the yield of an iron of known composition, and to say what quantity and composition of fettling would give the most satisfactory results. At present we only know that some of the "commonest," that is, the most impure irons, give the largest yield in the puddling furnace; but these irons lose most in the mill, the final result being approximately an equal weight of finished iron in each case. The quantity and quality of fettling also is usually arrived at by trial, frequently involving much loss from waste and trouble; and having once been determined, is often regarded as an important trade secret, and is rigidly adhered to, despite the variations which are usual in the pig iron to be treated. These remarks will perhaps be sufficient to indicate the incompleteness of our present knowledge, but it may be well just to point out that the information derived from other processes, or from crucible experiments, will in many cases prove but an unsafe guide to the understanding of the changes which take place in the puddling furnace.

To illustrate my statement that the explanations given of the

puddling process are frequently incorrect, and consequently misleading, we have merely to examine the usual chemical and metallurgical text-books. The late Dr. Percy, in his classical "Iron and Steel," was inclined to favour the view that during puddling phosphide of iron was separated by liquation, and he regarded the exact explanation of the removal of phosphorus as obscure. Greenwood, twenty years later (" Steel and Iron," 1884, p. 253), favours a similar view, stating that "the *rationalé* of its separation is not clearly understood." On the other hand, Miller (" Chemistry," 6th edit., 1878, edited by Groves, p. 624) states that silicon and carbon are removed during the earlier stages of the process, while sulphur and phosphorus resist oxidation, but are afterwards removed by the violent stirring of the puddler when the mass is becoming granular. Bauerman, again (" Metallurgy of Iron," 1882, p. 329), who gives a more than usually good account of puddling, says, "The removal of the foreign matters takes place in the following order—first silicon, then manganese, then phosphorus, and, lastly, sulphur." One further illustration will suffice. Hiorns (" Iron and Steel Manufacture," 1889, p. 88) gives merely the following naïve explanation:—" The ferruginous slag formed takes up oxygen from the air, causing FeO to pass into Fe_3O_4, which then oxidises the impurities in the order of their oxidisability—viz., silicon, manganese, phosphorus, sulphur, and carbon." It will be sufficient to remark, with regard to this extract, that the order given is not the "order of oxidisability" of these elements, and that when the elements are combined with iron the "order of oxidisability" depends altogether upon circumstances.

These quotations show that even in connection with such an important matter as the removal of phosphorus, one of the most fundamental reactions of puddling, considerable difference of opinion is expressed. Thus one author asserts that phosphorus is removed at the beginning of the process, another that it is eliminated at the middle, a third that it passes out at the end, and a fourth that it is eliminated uniformly throughout the whole operation. To make the matter complete, we only need some one to assert that it never passes out at all!

In view of such confusion, and bearing in mind that one reason for the continued prosperity of the puddling process is the fact

that it is most suitable for a class of irons too rich in phosphorus for use in the acid processes of steel-making and too poor for the basic processes, it is no wonder that practical men have felt inclined to pay but little heed to the theoretical aspects of their business.

The conditions which influence the success of the work in the forge may be divided into two classes, according to whether they are directly or but very indirectly connected with chemical considerations.

Of those conditions which are outside the province of the chemist, there is, of course, the fundamental question of finance, which is the backbone of all industry, but which cannot be discussed here. In addition, we have the necessary working conditions, which include:—

1. A furnace of suitable shape, size, and construction.
2. Fuel, which must be cheap, fairly pure, and of high calorific power.
3. Cheap and skilful labour.

In connection with suggested improvements in the first of these conditions, great hopes have been raised and enormous sums of money expended since this Institute was formed. And yet, in this country at all events, rotating or revolving furnaces after extended trial have been abandoned, double furnaces are seldom used, and any mechanical aid to the puddler is quite exceptional. Gas-firing too is but seldom employed, since with small puddling furnaces this leads to complications of ports and valves, to reduce which larger furnaces are necessary. Hence, to obtain the full benefit of gaseous fuel, larger blooms and fresh machinery would be necessary, and it is found more convenient to melt and cast the metal, since a sufficiently high temperature is at command, and thus steel is obtained.

At present, therefore, there seems to be no halting-place between the use of the ordinary puddling furnace on the one hand, and the manufacture of steel on the other. In the palmy days of the iron trade, the family of Crofts of Tipton were, I believe, the chief furnace-builders of this country; and the furnaces used in Staffordshire, which is the chief wrought iron-making district of the world, and hence may be considered representative, are still almost

exactly of the pattern then built. In some cases improvements have been introduced in the methods of cooling the bridge and sides; closed fire-places with forced draught, or fire-bars of special shape, are successfully used with small fuel, while the water-cooled doors used by Mr. Yeomans at the Old Hill Works, belonging to N. Hingely & Sons, Limited, are a great advantage to the puddler. Otherwise, so far as I am aware, there has been little alteration during recent years.

In dismissing the third condition of success above enumerated, I dare not attempt to discuss the great questions of to-day, upon which members of this Institute are divided; but I feel confident of this much, that the continuance of the Staffordshire iron trade has been rendered possible only by the fact that during the last fifteen years puddlers of unusual skill have been obtained at moderate wages, and that if this condition of things were seriously altered, it would be most disastrous to the trade of a district already heavily handicapped by its distance from the seaboard.

Among the conditions which come more directly within the province of the metallurgist and chemist, we have the composition, amount, and physical and other properties of—

1. The metal employed.
2. The fettling used.
3. The wrought iron obtained.
4. The cinder produced.

These conditions are naturally closely related to each other, and are to a large extent interdependent. Their proper understanding also necessitates an acquaintance with the nature and sequence of the changes which take place during the puddling process.

To discuss the question of the relative economy of forge irons of different chemical composition would involve more time and space than is at my disposal, and this is less necessary on account of the fact that during the last few years several papers have been published on this particular subject—the more important of which are those by Mr. A. E. Tucker and Mr. H. Kirk—which would well repay the careful perusal of those interested in the matter.* In

* The titles of these papers are as follows:—"Some Economies in Iron Manufacture." A. E. Tucker. South Staffordshire Institute of Iron and Steel Works Managers, January 22, 1887. "Valuation of Pig Iron for Forge Purposes." A. E. Tucker.

Mr. Tucker's second paper are to be found analyses of upwards of fifty samples of pig iron, most of them forge irons, and in the majority of cases the price of the iron is given with the analysis. Having had several opportunities of examining the large number of analysed samples of forge irons thus collected, I can testify to the interest and value of such a collection. Mr. Tucker emphasises the untrustworthiness of fracture as an indication of composition, and the extraordinary want of relation between some of the market prices of pigs and their real value, both of which are points of great importance. Mr. Tucker further shows how the approximate value of a pig for forge purposes may be estimated, the basis of his calculations being the statement that the process of puddling "consists in the absorption of silicon, sulphur, phosphorus, and manganese, contained in the pig iron, by the oxide of iron used in the fettling and in the removal of the carbon by the reduction of the fettling to metallic iron. We have, therefore, a debit and credit account, a loss in weight due to the bodies named, and a gain in weight due to the production of metallic iron from the fettling." Such a method of calculation is simple, and certainly enables one to distinguish between a good pig and a very bad one; but, after all, it is merely an approximation to the truth. For it is probable that some at least of the carbon is oxidised by ferric oxide without reducing an equivalent quantity of iron from the fettling; and it is pretty certain, on the other hand, that silicon, sulphur, phosphorus, or manganese may, under suitable conditions, be oxidised by ferrous oxide, and thus reduce some iron from the fettling. Hence the rule above given, though useful in many cases, fails to explain why an iron unusually rich in phosphorus and silicon often gives the largest yield of puddled bar, while a very pure iron will also yield a greater weight of puddled bar than that of the pig iron charged into the furnace, and an intermediate iron, of what may be considered good ordinary quality, loses 3½ 5, or more per cent. of its weight. It is in order to explain these apparent anomalies that, as I have previously pointed out, more accurate knowledge is required with reference to the action of oxide of iron on the various impurities in puddling.

Society of Chemical Industry, Birmingham, February 1888. Privately printed. "Further Improvements in the Puddling Process." H. Kirk. South Staffordshire Institute of Iron and Steel Works Managers, August 1878.

Before leaving this part of the subject it may be well to give the approximate composition of forge pig iron of typical kinds, as used in South Staffordshire:—

	No. 1.	No. 2.	No. 3	No. 4.
Carbon	2·60	3·60	3·00	not given
Silicon	1·20	1·25	2·00	·992
Sulphur	·08	not given	·10	·144
Manganese	·50	·50	·25	·693
Phosphorus	·57	1·00	1·80	1·233

No. 1 is an analysis of South Staffordshire all-mine pig, a turn of six full heats of which would require about 26½ cwts. of pig and 13 cwts. of fettling, while it would yield about 27½ cwts. of puddled bar. No. 2 is the composition of a standard pig for puddling, as used by Mr. Tucker for purposes of comparison; this will work into puddled bar with a loss of about 3½ per cent. No. 3 represents a cheaper part cinder mixture used in South Staffordshire, and which is not very different from Cleveland pig. No. 4 shows the average composition of a half year's pig iron of all sorts, best, crown, and common together, as given by Mr. Kirk in his paper above mentioned, and the yield, as verified from the firm's books after stocktaking, showed a loss of exactly 3¼ per cent. With an iron of this composition, Mr. Kirk has shown that seven heats per turn may be regularly obtained. I need scarcely add that such results are not merely unusual, but unexcelled.

The presence of some silicon is necessary in forge iron for the ordinary or "boiling" process, as otherwise the iron is "dry" and unsatisfactory in the furnace, though this can be to some extent remedied by the use of hammer slag or other silicious fettling. Generally, the cheaper forge irons in Staffordshire are too silicious and "hungry." This requires more time, uses more fettling, makes the cinder too thin, and gives a brittle bar. Some phosphorus is also an advantage in puddling, as it prevents the cinder from getting too thick at the end of the operation, and thus causing a variety of red-shortness. Too much phosphorus, on the other hand, leads to waste of iron and fettling, and renders it impossible to produce a good fibrous iron, unless, indeed, an unusually large proportion of fluid cinder is used, and the boil is conducted at the very highest attainable temperature. The presence of manganese

is an advantage, as it indirectly assists in the more complete elimination of phosphorus.

It is not possible to lay down any hard and fast lines as to a best or typical composition of pig for forge purposes. This will vary largely according to the local conditions, the fettling employed, and the quality of the product. In this country the pig iron made from the clay ironstone of South Staffordshire, South Wales, and West Yorkshire, is of the highest reputation, and chemically is all that can be desired; while, when it can be obtained, such an iron as that used by Mr. Kirk can be thoroughly recommended.

I do not propose to do more than incidentally touch upon the composition of the finished metal, and the rest of this paper will, therefore, be devoted to a brief consideration of the character and composition of the fettling used and the cinder produced.

It may, perhaps, in this connection, be of interest to some members to have on record a few details illustrating the practice of one of the oldest and best known firms in the South Staffordshire iron trade. For these figures I am indebted to the kindness of Mr. A. E. Barrows, who for some time past has worked in the Metallurgical Laboratory of the Mason College, and who is connected with the firm of William Barrows & Sons, of Bloomfield, Tipton. It will be remembered that it was at these works that the modern or "boiling" process of puddling was first introduced, more than half a century ago, by the late Joseph Hall, one of the early members of the firm, and the excellence of the iron made by this firm has been referred to by several metallurgical writers, including the late Dr. Percy, while their brand of B.B.H. is of worldwide reputation.

The iron used will, of course, vary with the class of work in hand, but consists of a mixture of about four brands of all-mine pig iron; such a mixture would contain about 0·55 per cent. of phosphorus. The weight charged is 4 cwt. 1 qr. 18 lbs.

The varieties of fettling used, together with the prices delivered at the works in March last, are as follows:—

	Per Ton. s.	d.
Best tap	17	0
Ore (purple)	13	6
Bull-dog	12	6
Do. ground	15	0
Roll scale	7	0
Hammer slag	1	0

Calcined pottery mine is also an important fettling in this district, but so far as I am aware hæmatite is not used.

The consumption of fettling, as calculated over a week's work of the above iron, was, per turn, averaging 25 cwts. 2 qrs., as follows:—

	Cwt.	Qrs.	Lbs.
Best tap	3	0	0
Ore	0	3	0
Bull-dog	2	2	0
Do. ground	1	2	0
Scale	1	1	0
Hammer slag	4	0	0
	13	0	0 per turn.

Or nearly 10¼ cwts. of fettling per ton of pig. It must be remembered that this is for best iron, and is more than is used by ordinary makers. The following figures give the weight of pig iron charged, the puddled bar obtained, and the cinder produced in three ordinary heats as above, the weights being taken for me for experimental purposes:—

Weight Charged.			Yield.			Tap Cinder Boilings.			Tap Cinder Tappings.		
Cwts.	Qrs.	Lbs.	Cwts.	Qrs.	Lbs.	Cwts.	Qrs.	Lbs.	Cwts.	Qrs.	Lbs.
4	1	18	4	2	14	1	1	0	1	1	0
4	1	18	4	2	14	1	0	0	1	1	12
4	1	18	4	2	7	1	0	20	1	2	0

It will perhaps be well, before proceeding further, to indicate what is the present state of our knowledge in relation to the removal of phosphorus in puddling, since this is probably the most important element from many points of view. So far as I am aware, the most trustworthy information is contained in Mr. Stead's papers on the chemistry of iron purification,* and to me it is

* "Phosphorus in Cleveland Iron Ore and in Iron." Cleveland Institute of Engineers, 1877, p. 132. "The Dephosphorisation of Iron." Cleveland Institute of Engineers, 1879, p. 134. "The Chemistry of Iron Purification." South Staffordshire Institute of Iron and Steel Works Managers, January 1884.

surprising that the valuable material contained in these papers has not met with greater public recognition. The correctness of Mr. Stead's conclusions has since been practically confirmed by Messrs. Harbord and Tucker. Briefly stated, the facts are as follows:—Under ordinary conditions of puddling, with a sufficiency of cinder and a fairly high temperature, a large proportion of the phosphorus is oxidised during the melting down of the pig iron, so that the melted metal frequently contains less than half of the phosphorus originally present. Phosphorus is further eliminated during the quiet period which precedes the boil, so that at the beginning of the boil the metal frequently retains not above one-fourth of the original amount of phosphorus. When the metal once becomes granular, or comes to nature, phosphorus elimination almost entirely ceases. The presence of silicon in excess retards phosphorus elimination; manganese acts in the same way when present in excess, but when part of the manganese has been removed, and the two elements are present in about equal proportions, they are rapidly removed together, and yield a very pure product. Oxide of manganese added to the slag does not appear to act like manganese in the pig, but the presence of an impure cinder at the latter part of the process may cause phosphorus to be once more reduced, and to pass back again into the iron. In short, the reactions in the puddling furnace closely resemble those of the basic Siemens process, which, of course, is what might be expected, since the fettling used is basic, and in each case the iron is melted in the furnace itself. Prior to Mr. Stead's researches, it was apparently the custom to regard the puddling and Bessemer processes as closely related, and that this erroneous view in part survives is shown by references I have given in the earlier portion of this paper. In the Bessemer process the metal is melted in a separate furnace, and the result is that the reactions of the acid and basic-lined converters not only differ from each other, but also differ from those of the puddling furnace. In the basic Siemens furnace, on the other hand, melting is performed in the furnace itself, and during the melting down, in a bath of rich cinder, it is quite possible, as Mr. Harbord has shown, to almost entirely remove the phosphorus originally present in the pig. It is also possible in the puddling furnace, with pigs which

do not contain too much silicon or manganese, and with suitable fettling, to remove almost the whole of the phosphorus during the melting-down stage.

In the puddling process, since the removal of phosphorus almost ceases when the iron is no longer fluid, a high temperature during the boil, and particularly in the early part of the boil before the damper is put down, assists in the complete purification of the iron, by keeping the metal longer in the fluid condition, and promoting the action of the cinder.

As it is necessary, before discussing the relative economy of various kinds of fettling and cinder, to have some definite view as to the constitution of puddling cinder itself, I will here venture to put forth my own views on this matter. In the earlier portion of this paper I have referred to the unsatisfactory manner in which fettling is often referred to as oxide of iron, while, as a matter of fact, ferric oxide (Fe_2O_3) alone is not a satisfactory fettling on account of its infusibility. In skilful puddling, the cinder plays a most important part, not only during the middle and end of the operation, but also during the melting-down stage itself; and he is a bad workman who, during the earlier part of his heat, has to make cinder either by the oxidation of his iron or by melting down his side or bottom fettling. In other words, there should be a sufficiency of fluid cinder present in the furnace to cover, and thus to clear, the iron as it melts. Having thus a bath of fluid cinder to begin with, the workman has then to rely upon his less fusible fettling, and partly upon atmospheric oxidation, to supply the ferric oxide he needs during the process.

Magnetic oxide of iron is produced when iron burns in air or oxygen, and is usually represented by the formula Fe_3O_4 (or FeO, Fe_2O_3), though there are considerable differences in the proportion of ferrous and ferric oxide found in various samples of native magnetite and in the artificial "best tap." This magnetic oxide is fusible, as is evidenced by the fluid cinder on an "oxide bottom," sometimes used in reheating furnaces when "best tap" is made. But though magnetic oxide is fusible, it does not melt nearly so readily as ordinary puddling cinder. Ferrous silicates, such as FeO, SiO_2, or $2FeO,SiO_2$, are readily fusible, but have little oxidising power, and the iron they contain is not easily reduced

by the action of carbon or other reducing agents. Good tap cinder if carefully crushed and freed by a moderately powerful magnet from any shots or globules of iron, is found to be almost wholly attracted by a powerful magnet, thus showing the presence of a considerable proportion of magnetic oxide of iron. In connection with some experiments of this kind, it struck me that as a small part of the crushed cinder is not attracted by a magnet, it might be possible in this way to separate the phosphorus or other impurities, and to obtain a fertiliser on the one hand and best tap on the other from puddling cinder. I therefore repeatedly treated a sample of such cinder with a powerful magnet, until a portion was obtained which was not attracted, while the whole of the rest, about 85 per cent. of the original, was attracted.

On analysis the following results were obtained:—

	Original Sample.	Portion not Attracted.
Silica (SiO_2)	17·12	18·06
Phosphoric anhydride (P_2O_5)	7·62	7·22

From this I conclude that no thorough separation of the sort I had in view was possible, and that the part attracted was merely richer in magnetic oxide of iron, while the part not attracted was richer in ferrous silicate.

These and similar considerations lead me to put forward the following suggestions. Puddling cinder may be regarded as being essentially composed of two substances—ferrous silicate and magnetic oxide of iron. The first of these is readily fusible, comparatively neutral so far as its influence on the constituents of the iron is concerned, and cheap. It can be obtained at an almost nominal cost in the form of hammer-slag, which still retains in addition a very appreciable and useful quantity of magnetic oxide Magnetic oxide itself, on the other hand, is less fusible, and with much ferric oxide is extremely refractory. It is an active oxidising agent, and is the chief constituent of the best tap, bull-dog, &c.; for it is erroneous to suppose that these materials consist of ferric oxide alone. During the puddling process, the more readily fusible silicate melts first, and then dissolves the magnetic oxide, or the still more refractory ferric oxide, which when dissolved forms magnetic oxide; and thus puddling cinder may be regarded as a solu-

tion of magnetic oxide, that is, of ferrous and ferric oxides, in ferrous silicate. Or, to put it in another way, just as the galvaniser uses hydrochloric acid dissolved in water to clean his sheets before coating them with zinc, so the puddler uses magnetic oxide of iron dissolved in a nearly neutral cinder to remove the impurities of his crude iron.

If the explanation thus given be the true one for puddling cinder, it is doubless to a large degree applicable to other processes where oxides of iron are used as oxidising agents, such, for instance, as the old-fashioned refinery, the American bloomery, the Swedish and Styrian processes for producing iron or steel in an open-hearth, and the "washing" processes introduced by Bell and Krupp. In all of these cases the slag obtained is silicious and fusible, and contains a variable amount of dissolved magnetic (or ferric) oxide. Further, it would appear that since, in modern puddling, the greater part of the oxidation which takes place is due to the action of the cinder, this question of the amount of the dissolved oxide is of the highest economic importance. The ferrous silicate melts easily, and can be used in a form which costs next to nothing, and obviously it must be economical to have the highest proportion of this material present which is consistent with good working.* On the other hand, ferric oxide (which is an essential constituent, and often the source, of magnetic oxide) is necessary, but dear. Too large a proportion of magnetic oxide, therefore, means preventible loss of fettling, while too small a proportion will involve the use of more time, a larger total weight of cinder, and consequent waste of fuel.

For these reasons I contend that a knowledge of the weight and composition of the cinder produced in puddling is of the highest practical value in enabling us to judge of the success of the process.

It will of course be understood that in these and the subsequent remarks I am merely endeavouring to elucidate the main principles which underlie the puddling process, and not to dogmatise or to lay down any hard and fast lines of procedure which it is obviously impossible to do in a case like the present, where the operation is conducted on small quantities at a time, on nearly all varieties of

* Though ferrous silicate itself has comparatively little oxidising power in the puddling furnace, it doubtless acts as a carrier of atmospheric oxygen from the furnace gases, and thus contributes to the oxidation of the impurities present.

pig iron, and with many kinds of fettling, and when success or failure is so often dependent upon the skill and attention of the workman.

In the ordinary process of puddling there are two distinct varieties of cinder produced, and the difference between the two is generally overlooked, though I think this difference is of great importance. The first variety of cinder is usually known as "boilings," from the fact that it boils over the foreplate during the heat, and is collected in the tapping-waggon. The second kind is known as "tappings," and is tapped out at the end of the process. The "boilings" are usually more or less honeycombed in structure, and are more easily fractured than the tappings, which are, on the other hand, more compact and dense. The tappings are free from metallic iron, while the boilings always contain some shots or globules of metal, which are carried over by the turbulence of the boil, and in some specimens recently examined I found as much as 16 per cent. of metal in the form of small globules, which were separated by a moderately powerful magnet from the crushed cinder.* These globules of iron still retain carbon, and, being in contact with an oxidising slag, they produce carbonic oxide, which burns in jets at the surface of the molten cinder. The tappings, on the contrary, usually evolve little or no combustible gas. I think it may be considered, as a general rule, if the tappings are very lively in the waggon while hot, and very honeycombed and brittle when cold, that the process is not so satisfactory as when the boilings are more quiet and compact. Now it is somewhat remarkable to find how differently experienced men work these two varieties of cinder. Thus, while Mr. Harrison, a manager of many years' experience in South Staffordshire, advocates the production of practically no boilings, but retaining the whole of the cinder in the furnace till the end of the process, the figures given by Mr. Barrows earlier in this paper show that at one of the best works in the district they produce about an equal weight of tappings and of boilings. And yet another manager, who would prefer to have his name unmentioned, but to whose experience and practical knowledge I attach the very

* See paper "Varieties of Tap Cinder." South Staffordshire Institute of Iron and Steel Works Managers, April 1891.

highest importance, recommends that so far as possible all the cinder should be boiled out, and only so much allowed to remain as can be carried to the hammer with the balls. But all will, I think, agree that the balls should, when taken to the hammer, retain a considerable quantity of tolerably thick cinder, which should so adhere to the iron as not to leave a trail behind on the way to be shingled, and yet which, when under the hammer, should cover and almost bathe the metal in slag.

For the purpose of my experiments, by the kindness of gentlemen who are or have been students in the Metallurgical Laboratory at Mason College, I obtained three sets of samples from different works—namely, samples of three heats from Mr. T. Ashton of Netherton, one heat from Mr. Tolley of Darlaston, and three heats from Mr. Barrows of Bloomfield. The samples therefore represented seven heats worked under ordinary conditions, and in each of which satisfactory iron was produced; they were collected from different works using various kinds of iron and varieties of fettling. In this way it was hoped to obtain a mean result, which would as fairly represent the general practice as is possible under the circumstances.

The samples were first crushed and treated with a magnet to extract any metallic iron that was present. In each case the boilings contained shots of iron, while the tappings were free from such metal. The mean composition, as deduced from the seven heats, was as follows :—

	Boilings.	Tappings.
Ferric oxide (Fe_2O_3)	6·94	12·90
Ferrous oxide (FeO)	62·61	64·62
Silica (SiO_2)	19·45	15·47
Phosphoric anhydride (P_2O_5)	6·32	3·91
Not estimated (MnO, S, CaO, &c.)	4·68	3·10
	100·00	100·00
Total iron	53·55	59·29

I have not ventured to calculate how much of the ferrous oxide was combined with silica and phosphoric anhydride and how much oxide of iron was free, on account of the uncertainty as to the exact composition of the silicates and phosphates of iron that occur in tap cinder. The above figures, however, show a marked difference in the composition of the two kinds of cinder,

the boilings being richer in silica and phosphoric anhydride, while the tappings contain more ferrous and ferric oxide, and consequently more iron. I know that blast furnace managers who use puddling cinder have a decided preference for tappings, and this is only what would be expected from the above analyses. This difference in composition is connected with the fact previously noticed, that the greater part of the silicon and phosphorus are oxidised during the earlier part of the process. Now, it is obviously necessary that these impurities should be oxidised and pass into the slag if a good product is to be obtained; but experience also shows that in order to produce a good iron it is necessary to have a fairly pure tapping cinder, as otherwise the impurities are either not wholly removed, or, if removed, they may actually pass back into the metal again. But if we wish to have economical working, the consumption of fettling must be reduced as much as possible; while, if we desire a pure product, the cinder must be rich and pure. How, then, are these too apparently opposite conditions to be obtained?

The purification of iron by oxide has been referred to as a "washing" process, and in an earlier part of this paper I have compared it to a "pickling" process. Certainly the final separation of slag from the granules of iron is not unlike the washing of a precipitate in the laboratory. If, for the sake of illustration, we consider the case of a quantity of oxide of iron contaminated with a soluble salt, and assume that the material will in the moist state retain one volume of the washing water. If then the oxide of iron be agitated with 100 volumes of water and filtered, the amount of remaining impurity will be only $\frac{1}{100}$ of the original quantity. But if the oxide were agitated with 10 volumes of water, and filtered, the impurity would be reduced to $\frac{1}{10}$; and if it were again treated in the same manner with 10 volumes of water, the impurity would now amount to only $\frac{1}{100}$ of that originally present. Thus, by twice washing with 10 volumes of water, we obtain the same result as by the use of 100 volumes with a single washing. Now it seems to me that this principle is applicable to puddling cinder, especially when very impure pigs are to be used. Enough fusible cinder should be used to produce a bath sufficient to cover the metal as it melts, and this cinder

need not be of an expensive character, since hammer-slag and similar materials are cheap. The character and proportion of ferric oxide in this cinder must, of course, be varied according to the pig to be treated, the object in each case being to remove the greatest possible amount of silicon and phosphorus at the beginning of the process. Having thus transferred the impurities from the pig iron to the cinder, and as far as possible *saturated the cinder with impurities* (which is, I believe, the key to economy at this stage), this cinder should be removed from the furnace, and this is most easily done, not by tapping at this stage, as was formerly the custom at some places, but by regulating the damper so as to produce a good boil, and thus boiling out the impure cinder into the tapping-waggon. Care must, however, be taken to avoid undue loss of metal in the form of globules at this stage, and the boiling cinder should be tested occasionally by crushing in a mortar, sieving, and treating with a moderately powerful magnet.

It must also be borne in mind that it is easy to spoil the iron by having either too little cinder or a too fluid cinder during balling, as this leaves the finely divided metal exposed to oxidising gases at a critical stage of the process.

In puddling unusually pure iron, or metal that is more apt to produce a deficiency than an excess of cinder, obviously the foregoing reasoning with regard to the boilings does not apply, and it may in such a case be best to produce little or no boiling cinder. The general practice of the present day is to use much more impure pig iron than was the case forty years ago, and hence the importance of a correct knowledge of the composition of cinder at different stages of the process becomes more necessary. It is perfectly certain that it is possible, by the use of a sufficiency of cinder, by thoroughly boiling the iron, and by boiling out a good deal of the first cinder, to produce a splendid bar iron from very impure materials, and the quality of the finished iron often depends more upon the details of manipulation than upon the chemical composition of the original pig iron.

The average composition of the three samples of tappings and boilings previously mentioned is given in the following table, from which it will be seen that the amount of ferric oxide in the boilings is fairly uniform, and does not vary over a wide range in the

tappings, while the other constituents show considerable differences, though in each case the same fact is noticed, namely, that the boilings contain more phosphorus and silicon, and less oxides of iron, than the tappings.

	Boilings.			Tappings.		
	1. Three Heats.	2. One Heat.	3. Three Heats.	1. Three Heats.	2. One Heat.	3. Three Heats.
Ferric oxide (Fe_2O_3) . .	6·28	7·53	7·40	12·24	11·61	14·00
Ferrous oxide (FeO) . .	59·91	63·96	64·86	59·83	67·46	68·46
Silica (SiO_2) . . .	19·31	17·12	20·38	18·12	11·02	14·29
Phosphoric anhydride (P_2O_5)	7·68	7·62	4·52	4·90	5·08	2·53
Not estimated . . .	6·82	3·77	2·84	4·91	4·83	0·72
	100·00	100·00	100·00	100·00	100·00	100·00
Total iron . .	51·00	54·91	55·63	55·10	60·60	63·05

But when it is found that, in slags from different works conducting the same process, variations exist which amount to more than 50 per cent. of the silica present (viz., 11·02 and 18·12 per cent.), and to just over 100 per cent. in the amount of phosphorus (2·53 and 5·08 per cent. respectively), the question naturally arises whether these slags are equally economical, and whether it is possible in any simple manner to determine the relative economy of various samples of puddling cinder.

To do this it is necessary to have some standard of comparison, and to obtain a satisfactory standard is not easy, while it would probably be impossible to get any one standard which would be of general application. Thus I can only hope to suggest an approximation to the truth. But it is fully settled I think that a puddling cinder may be an efficient purifier and yet contain as much as 20 per cent. of silica and 8 per cent. of phosphoric anhydride. Possibly even more impurities than this might be permitted, and with a reduction of silica more phosphorus could be allowed, and *vice versa.* Still experience shows that such a cinder is efficient, and we may, for purposes of comparison, regard this as a saturated boiling cinder. But the above table shows that we have usually about 5 per cent. of other constituents which were not separately estimated, while the ferric oxide is very fairly constant at about 7 per cent. Hence, as the composition of a boiling cinder for comparison, we may take—

Ferric oxide (Fe_2O_3)	7
Ferrous oxide (FeO)	60
Silica (SiO_2)	20
Phosphoric anhydride (P_2O_5)	8
Other constituents	5
	100

Such a slag as that above given contains scarcely any FeO in addition to that necessary to neutralise the SiO_2 and P_2O_5, on the assumption that the compounds 2 FeO, SiO_2, and 3 FeO, P_2O_5, are formed. On examining the table of analysis, it will be found that sample No. 1 agrees almost exactly with the suggested composition, while sample No. 2 is lower in silica, and No. 3 considerably lower in phosphoric anhydride than the standard. These are, therefore, unsaturated cinders, and are, for that reason, less economical, since either rather less fettling, or a cheaper kind of fettling, or a more impure iron, could have been used without interfering with the purification so far as the boiling stage is concerned.

If it is difficult to suggest a standard of comparison for boiling cinder, it is more difficult still to lay down any definite rule in the case of tapping cinder, on account of the variety in the quality of the iron to be produced, the weight of the tappings, and other causes. The following would, however, be tolerably economical and sufficiently pure for most purposes:—

Ferric oxide (Fe_2O_3)	12
Ferrous oxide (FeO)	60
Silica (SiO_2)	18
Phosphoric anhydride (P_2O_5)	5
Other constituents	5
	100

On comparing the table of analysis, it will be noticed that sample No. 1 is again very nearly of the character suggested, while No. 2 is low in silica, and No. 3 rather lower in silica, and considerably lower in phosphorus. It must of course be remembered that this sample is from very best iron, and the apparent extravagance may be to some extent necessary.

To appreciate the importance of this question, it is only necessary to calculate the effect of such difference of composition as is here noticed on the annual cost at a large works. Thus No. 3 sample of tappings contained 10·45 per cent. of Fe_2O_3 and FeO together in excess of what is necessary, if it is possible to work with the composition I have given. The oxide so calculated is pure, and equal

to best tap at 17s. 6d. per ton. The tappings are in round figures 1 cwt. per heat, or 6 cwts. per turn, or about 50 cwts. per week per furnace: 10 per cent. of this gives 2½ tons, which, at 17s. 6d. per ton, would cost £2 3s. 9d. per furnace per week, which, in an iron-works of the largest size, with, say, fifty puddling furnaces, would mean £5000 per annum.

Before closing this paper I should like to say a few words as to the probable nature of the changes which take place during the oxidation of the impurities of the pig iron during the puddling process. I have previously referred to the fact that a number of actions are possible, some of which involve the use of much more fettling than others, some of which yield much iron, and others none. Now, any explanation which may be suggested must be in harmony with the observed facts, such as:—That oxidation is carried on by oxide of iron, which is partly produced from the pig iron itself, but chiefly supplied in the form of fettling. Ferric oxide alone is too infusible to play an important part in the process, but acts when dissolved in cinder. Puddling cinder consists largely of ferrous silicate, which is readily fusible, but not easily reducible, and which amounts to two-thirds of the whole slag in the early part of the process. Puddling cinder contains magnetic oxide of iron, which is present in greatest proportion in the tappings. The amount of ferric oxide present is usually pretty constant at the same stage of the process in different heats and increases as the purification of the metal progresses. Impure pig irons do not necessarily give the smallest yield of puddled bar per unit weight of pig iron used, the contrary being particularly noticed with very common irons. The weight of puddled bar obtained may exceed the weight of pig iron used, especially if plenty of suitable fettling has been used, and the metal well boiled, so as to give a pure product.

Now, so far as I can at present see, these conditions involve the reduction of both ferric and ferrous oxides together according to an equation of the following type:—

$$x\ Fe_2O_3 + y\ FeO - zO = 2X\ FeO + y\ Fe,$$

in which, starting with ferric and ferrous oxides, by the removal of oxygen ferrous oxide and iron are obtained. If we consider ordinary magnetic oxide (Fe_3O_4), this equation would become

$$FeO,\ Fe_2O_3 - O_2 = Fe + 2\ FeO,$$

and such an equation probably represents a close approximation to what actually takes place in many cases, since we know that both FeO and metallic iron are produced. The relative amount of each will doubtless depend upon the conditions which exist in any case under consideration, and more particularly upon the proportion which exists between the oxidising power of the slag, and the kind and amount of impurities which have to be removed.

A consideration of the thermal aspect of this question supports the view that ferrous oxide or ferrous silicate take but little part in the oxidation under ordinary conditions. The heat developed by the combination of one gram of iron with oxygen in different proportions is approximately as follows :—

1 gram of iron oxidised to		Fe_2O_3	yields	1725	calories.
1	,,	,,	Fe_3O_4	,,	1600	,,
1	,,	,,	FeO	,,	1350	,,

By calculating from these numbers the amount of heat required to liberate the same quantity of oxygen for each of the three oxides, we obtain the following values :—

To liberate a unit weight of oxygen and produce metallic iron from	FeO	absorbs	1350	calories
,, ,, ,, ,, ,, ,, ,,	Fe_3O_4	,,	1200	,,
,, ,, ,, ,, ,, ,, ,,	Fe_2O_3	,,	1150	,,

Now, since more heat is required to obtain an equal weight of oxygen from FeO than from either Fe_3O_4, or from Fe_2O_3, obviously but little FeO will be reduced so long as higher oxides are present; but in tap cinder much, at least, of the FeO is already combined with either SiO_2 or P_2O_5, and this would render the reduction of the iron still more difficult. Of the remaining two oxides Fe_2O_3 is somewhat more readily reduced than Fe_3O_4, but much more infusible, and, as we have seen, oxidation is carried on in the puddling furnace chiefly by the fluid cinder which contains magnetic oxide. Hence it is not unreasonable to suppose that the infusibility of ferric oxide would counteract the slight advantage it possesses in reducibility, and that the main reaction is of the type above given.

Further support of this view is afforded by the results of some of my own experiments performed six years ago (*Jour. Chem. Soc.*, 1885, p. 474), in which it was observed that, on fusing silicon pig in a crucible with ferrous silicate, the proportion of silicon and manganese was but very slightly reduced, while these elements

were rapidly oxidised by slags containing ferric oxide, or by the action of atmospheric air. I then concluded that ferrous silicate, apart from atmospheric oxidation, has very little influence on silicon or manganese in pig iron, and stated that:—"From the fact that manganese is more readily oxidisable than iron, it might have appeared that ferrous silicate would itself probably act as an oxidising agent in removing manganese from pig iron. But these experiments appear to show that the real action of ferrous silicate is rather that of a carrier of oxygen than of a true oxidising agent. Ferric oxide is first formed, and this is reduced by the bath of metal present."

On the other hand, an experiment performed by Mr. Stead (*Cleveland Engineers*, 1877, p. 153), in which a small quantity of pig iron was fused with an excess of oxide of iron, chiefly in the form of ferrous oxide, appears to prove that phosphorus is oxidised by ferrous oxide, and that, at the same time, it reduces an equivalent amount of iron from the slag. This experiment is scarcely conclusive, as no account was taken of other elements present in the pig; but if ferrous oxide removes phosphorus and reduces an equivalent amount of iron, while silicon and manganese are oxidised by ferric oxide and reduce no iron from the slag, this would explain some of the apparently anomalous yields obtained with certain common irons, to which I have before referred. Too much importance must not be attached to crucible experiments, however, as the conditions are not the same as those which obtain in the puddling furnace, and additional experimental evidence is required in order to further elucidate some of these points.

It may, in conclusion, be necessary for me to again remind you that my paper is intended to partake more of the character of a contribution to the discussion of a subject which is of interest to many members of this Institute than as a dogmatic assertion of fixed and unalterable views; and if what I have said should be of use in assisting to clear up some points which are obscure, and in causing others with wider opportunities for practical observation to investigate the matter more fully, I shall feel that the object I had in view when this paper was commenced has been fully realised.

DISCUSSION.

The PRESIDENT said that discussions on the subject of the operation of puddling, and the changes going on in the puddling processes under circumstances which were advantageous or disadvantageous, had arisen from time to time at the Institute's meetings, and were to be found recorded in the annals of the Institute from an early date. This was always a subject of great interest, and the views that Mr. Turner had put forward might, perhaps, in some directions, give rise to the examination of the question from new aspects. They would be glad to hear the remarks of members on any points in the paper.

Mr. G. J. SNELUS, F.R.S., said he felt rather "sat upon" by finding that Mr. Turner did not appear to have seen his paper on puddling in the Danks furnace which was written nearly twenty years ago. He ventured to say that, if Mr. Turner would read that paper carefully, he would find a great many of the points he had named in his paper most clearly elucidated, and the questions of doubt that he had raised answered. That paper, as perhaps many of the old members would recollect, was written after the return of the Commission which was sent out by the Institute to examine the mechanical puddling furnace invented by Danks. He was fortunate enough to be the scientific adviser of that Commission, and it therefore fell to his lot to investigate most carefully what were the chemical conditions of the puddling process. It had been his good fortune to investigate that matter previously at Dowlais, and he believed it was because he had paid a great deal of attention to the chemistry of the puddling process that Mr. Menelaus had recommended him as the member to go out on that Commission; at all events, that was the reason given by Mr. Menelaus. He, therefore, claimed to have carefully investigated a great many of the points raised by Mr. Turner; and if any one would refer to the *Journal of the Iron and Steel Institute* for 1872, and look at that paper, he would find quite a number of those questions carried a great deal further than they had been carried in Mr. Turner's paper.

His friend, Sir Lowthian Bell, would well remember the hard hour's work between himself, Sir Lowthian Bell, the late Mr. Menelaus, and Mr. Edward Williams at Mr. Menelaus' house, where he (Mr. Snelus) was called upon, after his return from America, to explain to those gentlemen how it was that he accounted for the great increase in yield by the Danks' mechanical puddling furnace. He must say that they were not prepared for that increase of yield; the other members of the Commission were, he thought, a great deal more at home with puddling than himself, but they were all determined that they were not going to be taken in by their American friends in any question of fact. They therefore sat up and took their turn night and day to see that the weighings of all the material, in and out, were accurate, and that there was no mistake about them. They clearly proved, as a matter of fact, that there was a very large gain in the weight of puddled bar over the iron charged under all circumstances, and that was so against the notions of that time, that he knew Sir Lowthian Bell was very doubtful as to whether they had not been taken in, and as he had said he (Mr. Snelus) was called upon to explain how it could happen. His explanation was, that the metalloids present in the pig iron reduced the oxide of iron in the fettling, and that the reduced metal thereby entered into the puddled bar. Sir Lowthian Bell's words at that time were, "Well, I am quite free to admit that carbon will reduce oxide of iron, but I have my doubts whether silicon will do it. I am still further doubtful whether phosphorus and sulphur have power to reduce oxide of iron."

In order to set these doubts at rest, he (Mr. Snelus) had made what was now a rather historical experiment, and it was thus referred to at page 249 of his Report of 1872: "With regard to the power of silicon to effect the reduction of oxide of iron, some doubt has been expressed, and, as far as I am aware, the direct experiment has never been made. I have, however, made the following experiment, which, I think, proves the point conclusively:—5 grammes pure crystallised silicon were reduced to powder, and intimately mixed with 8 grammes Bilbao ore. The mixture was placed in a lime crucible, which was imbedded in well-burnt lime in an iron crucible, and exposed in the muffle of a Siemens steel furnace for two hours. When opened, a bulky

residue of silica was obtained, interspersed through which were fine metallic particles, and some small fused shots of metal. These were separated by the magnet, and by washing, and were found to possess metallic lustre, to reduce copper salts to the metallic state, and to give off hydrogen when acted upon by acids. As, therefore, solid silicon is capable of effecting the reduction of oxide of iron, it is almost certain that liquid silicon, as it exists in molten pig iron, must have the power to do so too." He believed that, since that time, it had been generally acknowledged that silicon had the power of reducing oxide of iron—in fact, he thought that was the dogma that was now universally accepted.

With regard to phosphorus, he was surprised to find that Mr. Turner had referred to it in these words: "The late Dr. Percy, in his classical 'Iron and Steel,' was inclined to favour the view that during puddling phosphide of iron was separated by liquation, and he regarded the exact explanation of the removal of phosphorus as obscure." Then he went on with some further remarks, and gave some statements about the removal of phosphorus, all of which he thought were rather wide of the mark, and especially in view of the experiments previously made. He was so much interested in the removal of phosphorus at that time, that he paid very great attention to it in the Danks process, because the problem of removing phosphorus in the Bessemer process had dawned upon him before he went to America, and he was then working at it; therefore he paid particular attention to the elimination of phosphorus during the puddling process. He might refer to the analysis of metal during the process of puddling given in his paper. He would take the crystalline pig iron, which was common pig iron selected by Mr. Menelaus, that they might take it out to see whether they could purify the worst pig iron that could be made. That iron contained 2·16 per cent. of phosphorus in the pig. When they came to puddle the iron, he took a sample the moment the iron became molten, and what was the result? That of 2·76 of phosphorus the whole of the metalloid had been removed except ·861 per cent.—more than 69 per cent. of the phosphorus had gone out of the iron while the iron was in a fluid state. He argued that that entirely upset the theory of his learned and

much-valued friend, Dr. Percy, as to the elimination of phosphorus by liquation. After he returned from America, he called upon Dr. Percy at the House of Commons, and had a long interview with him on the 25th March, and explained to him that his statement was wrong about the liquation of phosphorus. He said to Dr. Percy, "These experiments which I have made clearly show me that phosphorus is eliminated from the iron while it is in a fluid condition." He also said to the Doctor, "This, I think, enables me to remove the phosphorus in the Bessemer process." He went direct from Dr. Percy to a patent agent, and took out his patent, which was now, of course, well known. He therefore thought it was rather late in the day to begin raising the question as to whether the oxide of iron had the power of eliminating phosphorus or not. He thought experiments showed it most conclusively. That was not the only one. He had given a case in which phosphorus was the highest, but with Derbyshire pig iron he found that while the pig iron itself contained 1·04 per cent., very shortly after the iron was melted, long before it was puddled, and long before the process of liquation came into action, one half of the phosphorus had disappeared. So they traced it continually, going not because it liquated out as the phosphate of iron, but because it was oxidised directly by the fettling of the furnace, or by the atmosphere of the furnace, and passed away. If it was oxidised by fettling, it undoubtedly reduced the fettling itself either to a lower oxide, or, as he believed, mostly to the metallic state.

That was the way in which he accounted to their friends for the increased weight obtained in puddled bar. They had only four elements which could cause increase in weight; they had carbon, silicon, phosphorus, and a little sulphur. He thought if his paper were read through more carefully by Mr. Turner he would find a great deal to interest him. It was so long since the old puddling process came to the fore that one had almost forgotten it, and it came upon him almost as a sort of resurrection to hear that process referred to. He was pleased to find that Mr. Stead's experiments corroborated the statements which he (Mr. Snelus) had made, but he thought it was only fair that he should call attention to the fact that those investigations were made long prior to Mr. Stead's, and that they were fully confirmed by later experiments.

Mr. J. E. Stead said he must endorse what Mr. Snelus had said. So far as his own investigations on puddling were concerned, he considered they were confirmatory of Mr. Snelus's theoretical and practical report on the chemistry of puddling. They all knew that carbon would reduce iron from oxide in the puddling process. Mr. Snelus proved that silicon would reduce iron oxide, and advanced the theory that phosphorus would, when combined with iron, have a similar reducing action. The experiment Mr. Turner took exception to was made to prove the correctness or incorrectness of Mr. Snelus's theory about phosphorus. The experiment was incorrectly described by Mr. Turner, as he (Mr. Stead) had not used pig iron containing silicon, manganese, carbon, and phosphorus, but a pure compound of iron and phosphorus, and it was this phosphide of iron which, on being fused with a cinder containing the greater part of it protoxide of iron, gave a result most completely confirming Mr. Snelus's theory. The metallic button weighed more than before, and on analysis it was shown that some phosphorus had been removed and an equivalent proportion of iron reduced from the oxide. It was impossible to make such an experiment in a puddling furnace, and the only way possible to obtain reliable results was by heating the phosphide and oxide in a closed crucible. He thought Mr. Snelus would agree with him in what he had said.

Mr. Snelus—Yes.

Mr. Stead thought the investigations of Sir Lowthian Bell threw a great deal of light on the nature of the changes which were effected in pig iron when treated with fluid oxide of iron. He would advise those who superintended experiments in puddling furnaces to be very careful about making their conclusions, for it was a fact that the puddler, by extra work, endeavouring to make experimental trials successful, with the expectation of receiving a half-crown, produced, as a rule, superior iron in such cases. Many patentees had been misled in that way, and there was on record in the Patent Office a patent for improvements in making puddled iron in which is prescribed the addition of two young onions to the melted charge. When the trial was made there could be little doubt that the iron produced was of superior

quality, and that the inventor attributed it to the onions, and not to the extra mechanical work and care used by the puddler. His advice was, Don't superintend a puddler, but tell him what to do, and examine the products afterwards. The puddling process, at best, was a crude process, and difficult to control in the way that many modern processes could be. The skill, care, and regularity of the puddler were always varying. The quality of the coal, and size of the hearth, were also variable, and the composition of the slag could with difficulty be controlled, as slight differences of temperature caused more or less of the fettling to be melted away. Mr. Turner had not taken into consideration the great waste of iron which occurred at the time of balling up. In the Danks furnace the waste was not nearly so great because only one large ball was made, and the surfaces exposed to oxidising influences were much less in proportion. Sir Lowthian Bell, in his investigations into the Blair spongy iron process, had shown what great loss occurred when attempts were made to melt the sponge in an open-hearth furnace containing a bath of metal. They might be certain that in the puddling furnace the spongy ball was similarly affected.

Sir Lowthian Bell, Bart., said that the paper had been written, as Mr. Turner had said, in order to provoke discussion, and he thought it was well calculated to effect that object. But unfortunately Mr. Turner had done what a great many gentlemen did who had contributed papers to the Institute—sent them in at so late a period that no one who had great claims upon his time could by any possibility prepare himself to take up the questions involved in the manner in which they ought to be taken up. He believed that he had received the paper about three days before coming to London. He should have been glad to have been able to refer to the work that he had himself done in 1878, to which reference had been made by Mr. Stead. He was certain that he could have shown by what he had said in his papers, that there was a good deal of mistaken impression in the mind of Mr. Turner when he wrote his paper. He did not like then to take up the question, because, in controverting statements in such a discussion, one had to be prepared with exact figures in order to show whether Mr. Turner or Mr. Stead was correct. He wished that some members would devise a plan by which they could

render compulsory the sending in of papers some time before the meeting of the Institute. When they considered the great inconvenience and expense involved in attending the meetings, he thought that the very least that the authors of papers could do, having regard to the time and convenience of members generally, was to send in their contributions in sufficient time to give those who wished to take part in the discussion an opportunity of examining them. Fortunately, his friend Mr. Snelus had what he had said at his fingers' ends, and was able to turn to the passage and quote from it. He was sorry to have been reminded by his friend that upon the occasion of an interview which had faded from his (Sir Lowthian Bell's) memory, he had committed the indiscretion of questioning the accuracy of Mr. Snelus's opinion with regard to the puddling process. He had no doubt that the experiments afterwards performed thoroughly showed that Mr. Snelus was quite right, and that he (Sir Lowthian Bell) must have been mistaken. Of course there was a great deal in the present paper to which one might, in a small way, take exception. He saw some gentlemen present who had had a great deal of experience in puddling. He had himself for many years in the early period of his life attended to the subject, but that was the first time that he had learnt that some of the commonest kinds of iron afforded the largest yield in a puddling furnace. His experience was directly opposed to that. He had never found a very common kind of iron capable of giving a very good yield: it was generally the reverse. He would take the opportunity of looking through his own experiments, and perhaps he might be permitted, if he found it necessary, to add a few remarks before the *Transactions* went to press.

Mr. H. BAUERMAN said that his account of puddling referred to by the author was not written in 1882, but several years earlier (about 1866), and the inferences as to the order of removal of the different foreign matters in the process were deduced from the analytical evidence then available, which, so far as he remembered, were the researches of Schilling, Calvert, and Johnson, and some others, whose published analyses of metal and cinder taken at different stages of the process no doubt properly represented the conditions then prevailing, but which would necessarily vary from time to time, and with the method of treatment adopted. Indeed,

the paper showed that there was no uniformity of practice in South Staffordshire at present: the three possible methods of boiling all the cinder out, keeping it all in, and boiling part out and keeping the remainder being followed, probably with equally good results, in different forges, and the same diversity of practice obtains in the basic open-hearth process. As regards the constitution of the cinder, it would not be necessary to say much in addition to the remarks of Mr. Snelus and Mr. Stead. It might, however, be mentioned that the fact that ferrous silicate is practically inert, and that its oxidising power is due to dissolved magnetic oxide, had been known for a long time, and it is to this oxide that the black metallic character of crystallised cinder is due; the pure silicate in the natural mineral Fayalete being quite transparent and but very slightly coloured, and even the large crystals obtained in the earlier experiments on the Hollway process were translucent and of a green colour. In making these remarks, he desired in no way to depreciate Mr. Turner's able and careful work, which was worthy of all commendation, but he was rather surprised that Mr. Snelus's work, which represented the standard of modern knowledge of the subject, had been overlooked in the preparation of the paper.

The PRESIDENT said he wished to ask the members to thank Mr. Turner for his communication. He would himself lay great stress upon what Sir Lowthian Bell had said on the subject of papers generally. No doubt great inconvenience, and worse than inconvenience, arose from the frequency with which papers were received shortly before the meeting by the Council, so late, indeed, that it was impossible to circulate them amongst the members in sufficient time to allow of their being even cursorily considered. The main use of many papers, especially such as that of Mr. Turner, was to provoke a thorough discussion of the subject dealt with. It was for an exchange of views, results, and conclusions, that the meetings were chiefly held. They could read the papers comfortably at home when the *Transactions* were supplied to them, but the importance of the functions which the Institution exercised, rested chiefly upon facilities afforded for an interchange of ideas when they met together, and in order that this might be thoroughly secured, it was all-important that whenever any matters in the way of novelty, either as regards facts, or

as regards theoretical views, were brought before them at their meetings, these should have been well digested by them before they met to discuss the subject. He proposed a vote of thanks to Mr. Turner for his paper.

CORRESPONDENCE.

Mr. F. SCARF: While, as has been so strongly insisted on, many of Mr. Turner's conclusions are not new, surely the conflicting and contradictory statements made in standard works offer ample justification for, and indeed demand, some measure of repetition. There is no doubt that silicon, and to a smaller extent phosphorus, has the power of reducing iron oxide to metallic iron in the puddling furnace, but to what measure this action may be relied on, is but dimly guessed at. To the iron manufacturer the question of yield is an all-important one, and while to attain this end a pig containing not more than 1·25 per cent. of silicon is recommended on the authority of Messrs. Kirk and Tucker, I have found it utterly impossible to attain anything like a decent yield with less than double that amount.

I was much surprised by Sir Lowthian Bell's denial of the statement that "some of the commonest kinds of iron afford the largest yield in the puddling furnace." Accustomed to look upon this as an axiom, I immediately made some experiments, details of which follow, which give a wholly unqualified support to Mr. Turner's remark. Every care, guided by past experience, was taken that absolutely reliable results should be obtained. These and similar experiments go to prove that while sulphur and manganese decrease rather than increase the yield, a decided increase is produced by silicon, and to a lesser extent by phosphorus :—

Sample.	Silicon.	Phosphorus.	Waste in Puddling.
			Per Cent.
A	2·1	1·3	9·7
B	3·5	1·	7·8
C	2·66	1·58	7·1
D	3·7	1·69	5·2
E	3·15	2·83	4·2

A GRAPHIC METHOD FOR CALCULATING BLAST FURNACE CHARGES OR "BURDENS."

BY H. C. JENKINS, ASSOC. M. INST., C. E., F.C.S.

THE calculation of the respective amounts of the components of a furnace charge or "burden" is, although very simple, a somewhat tedious affair, and a method for facilitating the computations, originally devised by me for class demonstration in the Laboratory of the Royal School of Mines, seemed to be of sufficient interest to put before the members of the Institute.

For many purposes, the well-known logarithmic slide rule is invaluable, but in a complex calculation it requires much writing; and it appeared possible to perform the special calculations required to meet particular cases much better by means of a simpler computing scale. Professor Balling,* in his work on metallurgy, showed how easy it was to work out metallurgical questions by means of a graphic method, but the operation can be performed with greater facility by the aid of a special slide rule, sketches of which are given in the accompanying diagram. The rule consists of two equal scales at right angles, one of which (*a*) is fixed to a small board, whilst the other (*b*) is fixed at right angles to *a* upon a block (*c*), which is capable of sliding motion in a groove parallel to *a*.

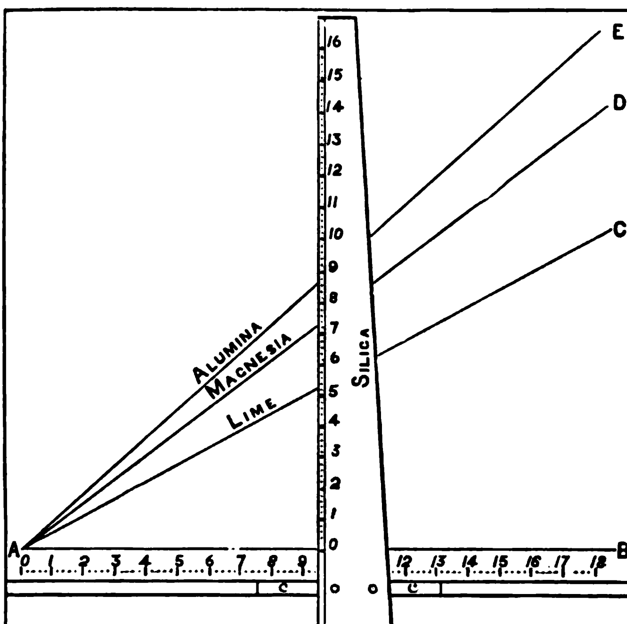
The point A, given by the intersection of the zeros of the two scales, is marked upon the board, and from it a line AB parallel to the groove is drawn. With A as centre, lines AC, AD, AE, are also drawn, making with AB angles whose tangents are equal to the ratios between the weight of silica to weight of base in the respective silicates which it is desirable to produce in order to form the typical fusible slags ordinarily met with in blast furnace

* Balling, *Metallurgische Chemie*, Bonn, 1882. Balling's method is described at length, with a diagram, in Professor Roberts-Austen's recently published "Introduction to the Study of Metallurgy." Griffin. London, 1890, p. 169.

practice. The lines AC, AD, AE, are marked with the names of the bases for which they have been calculated. Thus AC makes an angle of 28° 10′ with AB, this angle having a tangent whose value is ·5357, which is the ratio of the atomic weight of silica to twice the atomic weight of lime, and corresponds to calcium silicate; this line therefore is marked "Lime."

Similarly the line AD makes an angle of 36° 52′ with AB, the value of whose tangent is 0·75, or the ratio of the atomic weight of SiO_2 to the atomic weight of 2MgO; hence it is marked "Magnesia."

Also the line AE is at an angle of 41° 25′, and this, having a



tangent corresponding to the ratio of the atomic weight of $3SiO_2$ to that of $2Al_2O_3$, makes the line correspond to the values of the component parts of silica and of alumina in aluminium silicate, and so it is marked "Alumina."

With such a scale it is a very simple matter to at once read off either the excess of silica in any ore, or else the amount required to properly flux off the earthy bases present.

As an example, let us take an ore containing :—

		Silica Required.
FeO	50	...
MgO	3	2·25
CaO	5	2·68
Al_2O_3	3	2·65
SiO_2	3	...
CO_2	36	...

Then setting the movable scale *b* against 3 on the fixed scale *a*, and looking along *b* until the line marked "Magnesia" cuts it, we find the value 2·25 as being the amount of silica required to satisfy the magnesia. In like manner, we find the amount (2·68) of silica required for the lime, and the amount (2·65) for the alumina respectively; adding all these together, we find a total of 7·58 parts of silica required for every hundred of the ore. But there are already three parts present, so every hundred parts of the ore require 7·58 — 3 = 4·58 parts of silica to flux it. The gangue of the ore is basic to that extent, and the ore itself can be ticketed and known in the works as such, thus :—

C. 607.
FeO. 50 per cent.
Basic gangue, needing 4·58 per cent. SiO_2.

Another parcel of ore might be found to be deficient in bases, and to require, say, bases to neutralise four parts of silica to every hundred parts of ore. If it contained 46 per cent. iron, its label might be—

E. 1000.
FeO. 46 per cent.
Acid gangue, yielding 4 per cent. SiO_2.

If there is any considerable proportion of ash from the coke, as is often the case, it can be entered as acid or basic, just as in the case of an ore, thus :—

Acid, yielding 2 per cent. silica,

or :—

Basic, requiring 1 per cent. silica,

and the amount of silica for each part of iron produced added (or

deducted, as the case may be) to each ore in proportion to the number of parts of iron contained in it.

Any small quantity of sulphur can be treated as one-half its own amount of silica, or a special vertical scale (b_1) employed, the length of whose divisions are as 28 : 60.

If, as is usual, several kinds of ores are to be smelted together, they should be subjected to a preliminary mixing of an arbitrary character, so as to reduce them to three only. Of these, one should have *less*, and another *more* iron than is required in the final charge, and one should be acid and another basic after the correction for the ash from the coke is made. Or one of the three may be a limestone or a silicious flux; it need not necessarily contain iron.

Then let it be required to have n parts of iron per hundred of the charge, and let a_1, a_2, a_3, be percentages of iron in the ores, and b_1, b_2, b_3, percentages of deficiency (or excess) of silica in the same, and x, y, z, the number of parts required of the component ores per hundred of the charge.

Thus—

$$\begin{array}{lcl} & \text{FeO.} & & \text{Silica.} \\ x\,[a_1 & + & b_1] \\ y\,[a_2 & - & b_2] \\ z\,[a_3 & \pm & b_3] \end{array}$$

Then—

$$(1)\; x + y + z = 100$$

$$(2)\; \frac{xa_1 + ya_2 + za_3}{100} = n$$

$$(3)\; xb_1 - yb_2 \pm zb_3 = 0$$

Solving these simple equations, we have at once the number of parts of each component required to satisfy the conditions of the charge.

If it is desired to produce a more acid or a more basic slag, it only requires that the scale b_1 be replaced by one the length of whose graduations are one-half (for bi-silicate slag) or twice (for bi-basic slag) that of the normal scale.

A simpler form of the rule can be made by drawing the lines AB, AC, AD, AE, as before, upon a sheet of card, and then setting out a scale of equal parts upon the datum line AB, and providing a loose strip of card, one edge of which is graduated to the same scale, taking care, in using the scale, to keep it at right angles to the line AB. This is, in fact, the equivalent of a set of Professor Balling's diagrams, reduced to one scale and brought to a common centre.

The PRESIDENT said the members would no doubt desire to return their best thanks to Mr. Jenkins for his communication. Of course it was difficult to judge, by simply reading the paper, how far the method explained in it could be accepted as a thoroughly reliable one, but no doubt some gentlemen present would test it, and they would learn later on whether the communication for which they now tendered their thanks to Mr. Jenkins had proved of importance to ironmasters. There were two other papers to be read. One, however, would stand over, because Mr. J. D. Weeks, who had submitted a communication on the Coke Industry of the United States, would be able to make some additions to the paper if it were adjourned. The last paper was a very long one, by a gentleman very well known to the Institute—Mr. Jaques, late of the United States Navy—and dealt with the progress in the manufacture of war material in that country. A glance at the paper showed that it consisted very largely of descriptions of tests prescribed, and of the results of trials of material. He would therefore ask the Secretary to read it in an abridged form, in order that the members might have before them the gist of the paper. It would be a very valuable paper for reference, but it did not appear to be one upon which much discussion could arise.

RECENT PROGRESS IN THE MANUFACTURE OF WAR MATERIAL IN THE UNITED STATES.

By W. H. JAQUES (late United States Navy), Ordnance Engineer of the Bethlehem Iron Company.

So much interest has been taken in the recent progress of the United States Navy, and so much praise has been bestowed upon what has thus far been accomplished, that it will no doubt interest you to have a general outline of the present resources of this country for the production and supply of the materials that are entering into its construction.

In 1884 our facilities for building ships and guns were very limited and unsatisfactory; forgings for the heavy guns had to be purchased abroad, while iron shafts were employed instead of steel, because there were no forges in the country of sufficient power to properly shape and work them.

In that year the sources of ordnance supply were limited to the Midvale Steel Company and the small ordnance machine-shops at the Washington Navy Yard. Two years later official evidence showed that no private or public establishment was prepared to furnish the heavy masses of metal needed for the guns that are accepted by other nations as the best types, nor for the shafting and the heavy armour plates placed on the latest ships, nor for the turrets and casemates of shore defences. Our steel-makers stood ready to contract to furnish all such, however, and entertained no doubt of their ability to reproduce all the latest and costliest machinery that was needed to manufacture such metal of the best character. They lacked the experience needed for the immediate perfect production of the steel best adapted for heavy guns and armour, but the extraordinary ease with which they have always learned whatever they had sufficient commercial inducement to learn, justified the confidence with which they promised to supply, in quality as well as in quantity, whatever the Government might require.

The sequel has shown this to be the case; for while a review of

the present sources of supply shows only one great steel-making establishment, the Bethlehem Iron Company (which without any financial aid from the Government has erected, equipped, and put into operation a plant where all these products can be secured), the nation possesses two splendid and well-equipped gun-factories and a legion of other establishments, gradually but surely enlarging their capacity, covering every industry from the conception of the ship to its perfect equipment.

When entering upon his duties as Cabinet officer, the present Secretary of the Navy found the best types of each class of war material in hand or recommended by the heads of the various divisions of the Navy Department, and the mechanical means at his disposal for the supply of most of the products needed for the prosecution of the work laid down. The work has been developed with characteristic American rapidity.

Until recently, the Navy Department has been seriously handicapped for appropriations for experiments. Congress has always been very tenacious in its desire to retain jurisdiction as to what experiments should be made, as well as the details for ship construction, gun manufacture, &c., &c. Instead of voting a lump sum of the greatest magnitude that respective committees feel justified in allotting, and leaving the details to the technical officers and civilians who devote their lives to the development of the branches in which they are most interested, and for which they are educated, our Congressional committees feel it incumbent to govern the length, beam, and depth of hold of the cruisers, the thickness of barbette armour for each battle-ship, the coal capacity of the torpedo cruisers, or the effective reach of a torpedo, with the frequent result that the appropriations are inadequate for the specifications, and the designs have to be modified, seriously affecting their efficiency.

War-Ships.

Mr. Biles' very interesting paper on "Some Recent Warship Designs for the American Navy," contributed to the Institute of Naval Architects on March 19, has given such comprehensive history of the recent progress we have made in war-ship building, and is so fresh in your memory, that there remains for me but to

point out the sources of supply of the steel shafting and other parts of their marine engines, and to again call attention to the fact that while, up to the year 1888, these had to be purchased abroad (the shafting for the *Baltimore* and *Vesuvius* from Whitworth, and for the *Charleston* from Krupp), the Bethlehem Company then commenced a supply of shafting for the remaining ships, since which time that Company has been depended upon almost exclusively for this class of product.

Nearly all the forgings for the batteries of these ships have been supplied by, or contracted for, with this Company, and the contract for all the armour protection of the *Maine* and *Texas* has been awarded to the same works. The trial plate described in this paper was an information plate relating to the manufacture of the 11½-inch barbette armour for the *Monterey*.

The recognition of the ability of English designers has already been shown by the prize awarded Mr. John for his battle-ship, and the adoption of Mr. White's general designs for the *Charleston*, *Philadelphia*, and *Baltimore*.

Laying aside the question of how much of imitation may exist in the present designs, it is very gratifying to see the United States again in the race, and to find that we have made such gratifying progress.

There is much left to learn, however, by all nations, for our war-ships still lack coal capacity, boiler power, engine power, armour protection, and ammunition supply; everything, in fact, but displacement, and that we have too much of, the numerous weights soon aggregating a greater displacement than is sought.

Respecting the discussion of big ships or little ships, heavier guns, larger charges, heavier projectiles, greater velocities, bigger ships, bigger guns, thicker plates, larger torpedo boats and greater energies, larger torpedoes and heavier rams—these will all remain in the race for some time to come, and no nation will depend alone upon a myriad of sparrow ships, no matter how able they may be to inflict a great number of small wounds.

Ship, Boiler, and Protective Deck Plating.

A large number of steel-makers, notably near Pittsburgh,

possess plants capable of turning out this class of material, but the number offering to supply the Government with it is not large, owing to the numerous details and restrictions of inspection.

Messrs. Carnegie, Phipps & Co., and the Linden Steel Works, are the principal makers of this class of material, and both possess rolls of sufficient size to supply protective deck plating up to 3½ or 4 inches in thickness.

A contract has been awarded to the former for heavy armour plate, but the Company is not yet in possession of the machinery for its manufacture or handling.

The inspection of the material has been very severe, and much objection has been raised by some makers to the multiplicity of the details exacted. The following excerpta from the voluminous specifications indicate the United States' requirements:—

"All material, for which tests are herein prescribed, to be inspected and tested at the place of manufacture by a Naval Inspector of Material, and to be passed by him, subject to restrictions hereinafter mentioned, before acceptance by the Government for incorporation into said vessel.

"All such material supplied for these vessels to be clearly and indelibly marked in three places, and with three separate brands: first, the private stamp of the Inspector; second, the stamp of the manufacturer; and, third, with the regulation Government brand—the latter not to be stamped on any of the above material until the same has been inspected, weighed, and passed ready for shipment.

"Material may be rejected at the yard for surface or other defects, developed in working, though it bear the above-mentioned stamps.

"The acceptance of material under any test hereinafter provided for will not relieve the contractors from the necessity of making good any material that fails in working, or which may be rejected by the Inspector at the building yard.

"Test-pieces, after being cut from the plate, or the object to be tested, must not be subjected to any treatment or process, except machining to size, and such pieces shall not be cut off until the plate or object shall have received all treatment.

"Tensile specimens must be uniform in cross-section between

measuring points. Specimens of blooms, top layer of protective deck plating and forgings to have a length of 2 inches between measuring points, and a diameter of half an inch. Other tensile specimens must be 8 inches between measuring points, except specimens of rounds, not including rivets, which may be full-sized bars, eight diameters in length between measuring points.

"Manufacturers will furnish a chemical analysis, made in the most approved manner, of each heat.

"The Department shall have the right to keep Inspectors at the works, who will have free access to all parts thereof, and who will be permitted to examine the raw material and to witness the processes of manufacture."

Ship Plates and Shapes.

Kind of Material.—Plates and shapes to be of steel made by the open-hearth process, and must not show more that 0·06 of one per centum of phosphorus, nor more than 0·04 of one per centum of sulphur, and must be of good quality in other respects.

Tensile Tests.—Plates and shapes may be tested by heats as follows:—

Four test-pieces, each from a different plate or object, shall be made and tested for each heat as finished at the rolls.

Such test-pieces shall show a tensile strength of at least 60,000 pounds and an elongation in 8 inches of at least 25 per centum. If but one of such pieces fall below 60,000 pounds, but not below 58,000 pounds in tensile strength, or below 25 per centum, but not below 23 per centum, in elongation, showing either or both of such deficiencies, and the average result of the tests of the four pieces shows a tensile strength above 60,000 pounds, and an elongation above 25 per centum, the heat shall be accepted, if the other conditions of test are fulfilled. But if two such pieces fall below a tensile strength of 60,000 pounds or an elongation of 25 per centum, or if each of the two pieces fail in either characteristics, the heat shall be rejected.

The tensile tests of any single plate or shape may be regarded as satisfactory, provided it shows a tensile strength of at least 60,000 pounds and an elongation of at least 25 per centum.

Cold-bending Tests.—Two pieces to be cut from each heat as

finished at the rolls for cold-bending test, and they must bend over flat on themselves without sign of fracture. If one of these specimens fail, an additional piece may be taken, but if this one fail, the heat may be rejected. The number of pieces under this test may be increased if the Inspector has reason to suspect overheating or cold rolling.

Quenching Test.—Two pieces shall be cut from each heat as finished at the rolls for quenching tests, and after heating to a dark cherry-red, plunged into water at a temperature of 82° F. Thus prepared, it must be possible to bend the pieces so that they shall be doubled round a curve of which the diameter is not more than one and a half times the thickness of the piece tested, without showing any cracks. The ends of the pieces must be parallel after bending. Quenching and cold-bending pieces must not have their sheared or planed sides rounded off, the only treatment permitted being taking off the sharpness of the edges with a fine file. At the option of the manufacturer, the quenching pieces may be cut half an inch thick instead of the full thickness of the plate.

Surface Inspection.—Plates and shapes must be free from slag, foreign substances, brittleness, hard spots, laminations, sand or scale marks, scabs, snakes, pits, and surface defects generally. Shapes must also be free from defective sections, shaded backs, grooved fillets, imperfect edges, &c.

Protective Deck Plating.

The bottom layer of plating will be inspected as ship plates. The top layer will be inspected as follows:—

Tensile Tests.—Tour test-pieces, each, if practicable, from a different plate, shall be taken from each heat as finished. Such pieces shall show a tensile strength of at least 80,000 pounds, and an elongation in 2 inches of at least 18 per centum.

The tensile test of any single plate may be regarded as satisfactory, provided it shows a tensile strength of at least 80,000 pounds, and an elongation in 2 inches of at least 18 per centum.

The tensile test of any single plate having a tensile strength of at least 75,000 pounds will be regarded as satisfactory, pro-

vided the elongation is augmented by 0·5 of 1 per centum for every 1000 pounds less than 80,000 pounds in such a manner that at 75,000 pounds the corresponding elongation shall be at least 20½ per centum.

BOILER PLATE.

Kind of Material.—Steel for boiler plates must be made by the open-hearth process, and must not show more than 0·035 of one per centum of phosphorus, nor more thon 0·04 of one per centum of sulphur, and must be of the best quality in other respects.

One tensile test-piece shall be cut from each plate as rolled for boilers, either longitudinally or transversely, as directed by the Inspector, and one piece to be used as a bending-piece.

Tensile Tests of Shell Plates.—Transverse specimens must show a tensile strength between 58,000 and 67,000 pounds, with an elongation of at least 22 per centum in 8 inches. Longitudinal specimens must show a tensile strength between 58,000 and 67,000 pounds, with an elongation of at least 25 per centum in 8 inches. The elastic limit must be at least 32,000 pounds per square inch. A variation in elongation of 2 per centum below that specified will be permitted in the case of additional tests made by the Inspector to detect lack of uniformity.

Tensile Tests of Furnace and Flange Plates.—Test-pieces must show a tensile strength between 50,000 and 58,000 pounds, with an elongation of 26 per centum in 8 inches, either longitudinally or transversely.

Cold-bending Test.—One piece to be cut from each shell plate as finished at the rolls for cold-bending test, which must bend over flat on itself without sign of fracture.

Quenching Test.—One piece shall be cut from each furnace or flange plate as finished at the rolls for quenching test, and after heating to a dark cherry-red, plunged into water at a temperature of 82° F. Thus prepared, it must be possible to bend the piece so that it shall be doubled round a curve of which the diameter is not more than one and a half times the thickness of the piece tested, without showing any cracks. The ends of the pieces must be parallel after bending. Quenching and cold-bending

pieces must not have their sheared or planed sides rounded off, the only treatment permitted being taking off the sharpness of the edges with a fine file.

Connecting and Piston Rods.

From each end of each rough-forged steel connecting and piston rod a tensile test-piece shall be cut. Specimens may be taken from the heads or from a prolongation of the rod, but in no case must the piece from which specimens are cut receive more work than the body of the rod.

Tensile Test.—No test-piece must show less tensile strength than 65,000 pounds for connecting rods, nor an elongation less than 24 per centum in 2 inches. Test-pieces from piston rods must show not less than 58,000 pounds tensile strength, and an elongation of not less than 26 per centum in 2 inches.

Bending Test.—Bars one-half inch thick, cut from the piston rod forgings in the same manner as the tensile test-pieces, must stand bending double to an inner diameter of 1½ inch after quenching in water at 82° F., from a dark cherry-red heat, without showing cracks or flaws. Similar pieces to be cut from the connecting rod forgings must stand cold-bending double to an inner diameter of 1½ inch.

Crank, Thrust, Line, and Propeller Shafts.

Each length of rough-forged shaft must have a piece cut from each end of sufficient size to allow of the removal of specimens for tensile test, parallel with the axis of the shaft.

From the piece removed from the end which was uppermost in the ingot, four test-pieces shall be taken—two at the circumference of finished diameter, and two at one-half radius from centre. Two specimens will be taken at one-half radius from centre of the other piece. At the option of the manufacturer the above pieces may be taken at right angles to the axis, and at right angles to the shaft radius. These pieces to be broken under the same conditions as prescribed for tensile tests. In the case of hollow shafting (either forged or bored), the inside specimens

will be taken within the finished section prolonged, but as near as practicable to half radius from the centre.

If the couplings are forged on the shaft, test-pieces may be taken from a prolongation of the shaft forged to its least diameter.

In the case of solid forged crank-shafts, in addition to the test-pieces above specified, two test-pieces will be cut from the metal slotted out from each crank, one from the surface of the metal slotted out, and one at a distance of one-half the radius of the shaft from the plane passing through the axis of the shaft and crank-pin.

In the case of built-up crank-shafts, test-pieces will be cut from each separate forging of the shafts.

Tensile Test.—No piece must show less tensile strength than 50,000 pounds. The average elongation of the four pieces from the upper end must be at least 28 per centum in 2 inches. The average elongation of the two pieces from the lower end must be at least 28 per centum in 2 inches. No piece must show less than 24 per centum elongation in 2 inches.

Quenching Test.—Bars one-half inch thick, cut at the outer radius, must stand bending double to an inner diameter of 1½ inch after quenching in water at 82° F., from a dark cherry-red heat, without showing cracks or flaws.

Steel Castings.

Kind of Material.—Steel for castings must be made by either the open-hearth or the crucible process, and must not show more than six hundredths of one per centum of phosphorus.

Treatment.—All castings must be annealed unless otherwise directed.

The specimens may, at the discretion of the Inspector, be cut either from coupons to be moulded and cast on to some portion of the casting, or from sinking heads, in cases where such heads of sufficient size are employed. Coupons to be so fixed as not to interfere with the successful making of the casting, but at the same time showing the average quality of the material. In the case of castings tested by lots, the test-pieces may be taken from

the body of a casting from the lot, if so desired by the manufacturer.

Tensile Test.—The tensile strength of steel castings shall be at least 60,000 pounds, with an elongation of at least 15 per centum in 8 inches for all castings for moving parts of the machinery, and at least 10 per centum in 8 inches for other castings.

The tensile test of any single casting will be considered satisfactory, provided it shows a tensile strength of at least 60,000 pounds and the required elongation.

Bending Test.—Bars of the same metal, one inch square, shall be capable of bending cold, without fracture, through an angle of 90°, over a radius not greater than 1½ inch.

ARMOUR.

As this subject is one of such paramount interest at the present moment, and has been so earnestly and recently discussed, I venture a fuller reference than was at first my intention, hoping that further discussion will throw more light upon a much-vexed topic.

Mr. Biles has said that the making of armour was a question more for iron and steel manufacturers to discuss, the working of it into a finished design of a ship being the business of the naval architect; but I am sure that many steel-makers will join me in the hope that Mr. Biles and his fellow naval constructors will in their future designs for ships and their protection, their motive power and their armament, simplify as much as possible the forms of the great masses of iron and steel that have become such a necessary part of naval construction.

In the Annapolis plate trials of September last, the British compound system (Charles Cammel & Co., Sheffield) had a most excellent occasion for an exhibition of its qualities, their agents in the United States being enabled to present every favourable estimate of the British compound armour that they possessed. Their long experience as importers of foreign steel undoubtedly fitted them to lay before the Secretary all that was most favourable in the manufacture of their client's particular type of ship protection.

The Annapolis trials, which cannot be too strongly commended for their comparative excellence, would have been much more complete if Messrs. Brown & Co., of Sheffield, had been invited to send a plate for trial. I understand their representative in the United States did not suggest their entering the competition. This is to be regretted, for in many comparative trials of the plates of the two representative Sheffield makers the Brown plates have shown considerable superiority over the Cammel, while in the Ochta trials of November 11, 1890, the existence of *through* cracks in the Brown plate indicated a better weld than ordinary.

At Annapolis the victory for steel armour was so overwhelming, that the small difference, if any, which existed in the ballistic resistance of the two steel plates only suggested to my mind the necessity for additional experiments with nickel and other alloys, and methods of treatment with the view of combining, if possible, *all* the excellent characteristics that both plates displayed in the severe tests to which they were subjected.

As both steel plates were eminently superior to the Cammel plate, another decisive victory for steel was secured in a competitive trial which was conducted with the strictest equality of conditions.

It has been stated that the Cammel plate was not a fair average sample of the Wilson type; but whether the plates tried at the various competitive trials were fair average representatives of their type or not, they ought to have been.

At the last meeting of the naval architects, Mr. Biles took most excellent ground in relation to this when he stated that manufacturers should not make a mistake which would seem inexcusable for so important a result.

In general it can be axiomatically stated that in a comparison of plates tested in competitive trials, the arguments that are offered that haste in delivery or deficiency in manufacture have rendered them inferior to those of current make should not be allowed to enter. The manufacturers ought to guard their own interests by sending the very best plates they can make.

In congratulating Mr. W. H. White upon the successful accomplishment of his naval construction budget, and the remarkable

results that have been obtained in shipbuilding since his accession to the Admiralty, I cannot but regret that he has not yet added to his record the history of the competitive trial, on British soil, of all the various types of armour plate that are now so seriously engaging the attention of naval constructors and ordnance engineers.

He has referred to a 4-inch nickel-steel plate, from a test of which, he says, very interesting data have been collected. If he could procure the publication of these results, together with a full unbiassed report of the Nettle trials, he would undoubtedly be able to remove much of the prejudice that now exists with regard to them, and which can hardly be designated as an unjust prejudice so long as the public is kept ignorant of all the facts, except such as it may be to the interest of each individual manufacturer to publish.

In relation to the 4-inch nickel-steel plate, I would like to ask Mr. White with what calibre of gun, type of projectile, velocities, &c., this plate was tested.

Although reference has been made to experiments with nickel-steel armour plates in England, from all I can learn, no nickel-steel plates of the thickness, other dimensions, and mass of the one that was tested at Annapolis have ever been tried in England.

The great value of the Spezzia trials of October and November 1884, and the Annapolis trials of September 1890, is their fairness, openness, and equality of tests, by which means *only* can strictly useful comparative results be obtained.

The desire of Governments to keep from their rivals the results of tests is only natural, but if any statement is made concerning them, the whole truth should be given, in order to enable artillerists and metallurgists to make comparisons which will be of any scientific value.

With European Governments, and with Great Britain especially, the pride of protecting their industries keeps up the fight for the defence of compound armour. With most manufacturers it is the pride which essentially accompanies the success of their systems, while with some royalty obligations are the principal incentive. The United States appears to be the only Power where all this is ignored, in fact ignored to such an excess, accompanied by the desire to get something different and cheaper, and more quickly,

that the manufacturers assume serious risk when they undertake the supply of material which is to extend over such a long period as to permit their orders to be affected by the political and personal interests which so frequently govern legislation.

If the Nettle trials of 1887–89, and the Ochta trials of November 11, 1890, had been made under similar conditions to the Annapolis trials of September 1890, much valuable data might have been added to that already on hand, to assist in defining the comparative resisting powers of modern armour plates, and securing the unanimous opinion of many authorities who are now at such variance regarding the results of these trials. The first have subjected officials and manufacturers to unfavourable criticism, perhaps unjustly, while the last have excited a competition and development of ideas and systems and treatment never before witnessed in the consideration of such matters.

These views are not by any means new, either to the writer of this paper or to his auditors or readers, for both of your public service journals, *The Engineer* and *Engineering*, have repeatedly called attention to them, not only advocating, but urging what seemed to them the proper consideration of this very serious subject.

I have even personally urged your Chief Constructor, Mr. White, whose success and ability I had already recognised by recommending the adoption by the United States of the designs of a fast cruiser (the last he designed before his departure from Armstrong, Mitchell, & Co.), to secure a competitive trial that would, at least for the present, give such definite data as would leave no doubt as to which system (all-steel or British compound) provided the best defence against the probable attack of modern sea-fighting. In this, however, the United States Navy Department has now anticipated him.

If you are not willing to acknowledge the superiority of all-steel armour over Sheffield compound, you must believe it to be equally good; hence one ship armoured with French steel would not in any way weaken your navy. You can afford it, for you have more engineers interested in the results than any other nation; more manufacturers interested in the industry, and consequently more at stake, than any other nation. If Messrs.

Schneider set up the temporary obstacle of requiring an order for the armour of one ship as a condition of success, why not grant such a condition? You would lose nothing by it, for, as Mr. Burnaby says, no doubt the Admiralty would have agreed to give the order if when the plate had been tried it had proved satisfactory.

You have given an order to Messrs. Vickers because the success of his all-steel plates warrant it, and I believe that you would do the same without hesitation to Messrs. Schneider. This would lead quickly to the production of similar plates in your own territory, particularly as Mr. Alexander Wilson has stated that his firm is one of the largest makers of *steel* armour, as well as compound; and your Sheffield compound armour plate makers would, lose nothing, save perhaps a decrease in the royalties which one firm may yet have due under its contract with various makers.

Mr. Vickers made a most interesting statement regarding the Nettle trials. He said: "With regard to the Nettle trials, I do not agree with either Mr. Wilson or Mr. Ellis; if I could lay the full results of the trial before the meeting, I think it would be seen that our two plates were the best."

In 1886 I concluded a paper on the subject of "Modern Armour," * with these words: "In regard to future development I am not alone in the belief that the progress is limited to steel. Whether the best steel plate will be compounded mechanically—and there are those who believe they have devised the means—or whether the Schneider hard front and soft back will reach the highest development by the means he now employs, the future must decide."

There have already been produced compound steel plates that have shown far better results than have ever been obtained with British compound, while many other mechanical devices are being experimented with which promise excellent qualities.

The future is rapidly compassing a decision, and the Annapolis trials of September 1890 have, I believe, done more to expedite it than any others.

The method of their conduct gave them a prominence that could not have obtained in any other way.

* "Modern Armour for National Defence." New York and London: G. P. Putnams' Sons.

Much was promised from Mr. White's endeavours of 1886 and 1887 to secure for competitive test a large number of plates from all the big steel-makers of Great Britain, from whom he invited sample plates, including one from Creusot; but there resulted *private* trials of only a few of them under varying conditions; and thus far only such information has been made public by the various representatives interested as most naturally would commercially benefit them.

It is unfortunate that the Kolpino plate could not have been tested in the same public manner, and under the same conditions, as the other plates tried at Ochta on November 11, 1890, for the peculiar privacy attending this particular plate, and the variety of opinions as to the nature and quality of the projectiles used, naturally excludes it from comparison. In this connection I am glad to quote the opinion of *The Engineer*, so long a defender of Sheffield compound armour, that—"We maintain that compound armour has suffered by the yielding of the soft mass of the foundation plate of wrought-iron, and that steel has stood up better to the blow of the shot under most conditions. Consequently, the mass of the compound armour ought to be made of harder material. We believe that harder iron is now being employed. We are sorry to hear it, for steel must, in the long-run, beat iron, and we regard the most hopeful plate to consist of a hard steel face, with a softer steel back or foundation. It may be asked, will this beat solid steel of the same quality throughout? This we think entirely depends on the power of the face plate to adhere to the foundation.

"The difference in principle between compound and all-steel may be summed up as follows: *The compound has a face made of steel of a harder kind than can be got from the action of any special treatment on metal suitable for the back or foundation. This it obtains at the cost of a junction of the two metals.*"

By cementation and subsequent working and treatment, equal hardness can doubtless be obtained, but probably at the cost of brittleness and cracking. A harder face *has* been obtained by cementation and cold hardening of the solid steel plate than by the usual compound attachment.

This was done in the case of the 10½-inch untreated Creusot steel plate, subsequently treated by the Harvey process at the

Washington Navy Yard, and tested at Annapolis with a variety of Holtzer and Carpenter armour-piercing shells.

Mr. Kirchhoff, the able editor of the *Iron Age*, has given in that journal's issue of March 19, 1891, the best description of these tests yet made public. As you will no doubt be interested in them, I have inserted such details and drawings as will describe the results obtained.

"THE HARVEY ARMOUR PLATE.

"*Results of the Recent Trial at Annapolis.*

"We are indebted to B. G. Clarke, the well-known iron and steel manufacturer, for the following data on the trials of the Harvey armour plate, in the development of which both he and Theodore Sturges of the Oxford Iron and Nail Company have taken a deep and active interest, the inventor being H. A. Harvey, of the Harvey Steel Company, Newark, N.J. Mr. Harvey has applied his method of treating steel to armour plate, the plate officially tested at Annapolis on March 14 being of Schneider make, 10 inches thick and 6 by 8 feet. In order to afford a ready means for comparison we have added, in the accompanying supplement, a reproduction of a photograph showing the appearance of the three plates at the famous Annapolis trials, the plate to the extreme left being the all-steel Creusot, the one in the middle the nickel-steel Creusot, and the one to the right the Cammel compound plate.

"We print fac-similes of the appearance of the Harvey plate after the second and fifth rounds, and outline drawings showing the effect of the other rounds.

DATA FOR ALL ROUNDS.

Gun	6-inch B. L. R., No. 88 (35 calibres).
Distance from muzzle to plate .	263 feet.
Charge	44½ pounds, index 90.
Muzzle velocity	2091 f. s. (measured for first round only).
Striking velocity	2065 f. s.
Weight of projectile	100 pounds.
Temperature	40° F.
Angle of plate with normal to line of fire	13° 22′.

"In the treatment the Harvey plate had become warped in two directions—the face being approximately spherical with slight curvature—distance from rear face of plate at centre to chord drawn between corners of plate, 3 inches. The plate was secured to 36 inches of oak backing in the usual manner adopted with Schneider plates, and the backing secured to the structure used for the compound plate in the September trials. The space left at the back of the plate, owing to its warping, was filled in with oak fitted to its curvature. No side plates were used.

"*The First Round.*—Projectile, Holtzer A. P. No. 12. Point of impact, 2 feet from right edge, 23 inches from top. Projectile broke up into very small fragments, which were scattered over the grounds. Very few pieces could be recovered. A portion of the head was left in the indent so welded to the plate that when it was knocked out by subsequent impacts it carried portions of the plate with it, and it is impossible to give the depth of the indent with any accuracy. The point was judged to have been between 3½ and 4 inches below surface of plate. The depth, including portions of plate carried away, was 4⅝ inches; diameter at surface of plate, 9 to 9½ inches. No fringe was raised. A through crack 30 inches long was started downward and to right to edge of plate. A second through crack 19 inches long upward and to the left to top of the plate. No surface or hair cracks could be detected, and no radial cracks. The face of the plate in the neighbourhood of indent did not peel off, but the diameter at surface of plate was greater than usual.

"*Second Round.*—Projectile, Holtzer A. P. No. 35. Point of impact, 2 feet from top, 23 inches from left edge. Projectile broke up badly. Portions of base recovered near target. Portion of head left in indent, in the same manner as in round 1. Character of indent very much the same, but judged to be about ½ inch deeper. Depth, including portion of plate carried away with projectile, 5 inches. Diameter at surface, 9 to 9½ inches. No fringe. Through crack 18½ inches long to top of plate. Through crack 18 inches long to left edge of plate. Partially through cracks 16 inches long joining indent with No. 1, subsequently opened up to wide through crack. Partially through

crack 33 inches long downward and to left, subsequently opened up to wide through crack to left edge of plate.

"*Third Round.*—Projectile, Carpenter 208 C. Point of impact, 2 feet from bottom, 23 inches from left edge. Shell broke up badly. About the same amount of the base recovered as in second round. Character of indent very much the same, except that it was possible to separate the shell from plate. Depth of indent, 4 inches. Diameter, 9 to 9¼ inches. Very slight fringe about small portions of indent. Through crack down and to right, subsequently continued to bottom of plate, 27 inches long. Through crack up and to left to crack from first indent, 23 inches. Surface crack 18 inches long to left edge of plate.

"*Fourth Round.*—Projectile, Carpenter 207 C. Point of impact, 2 feet from bottom, 2 feet from right edge. Projectile broke up badly. About the same amount of base recovered as in rounds 2 and 3. Head remained in indent, showing end of powder chamber. Before firing this point was 7·02 inches from point of projectile. On attempting to remove the head, however, it appeared much flattened, and was so welded to plate that it was impossible to tell how far into the plate the point had reached. It was judged to be something less than 4 inches. Character of indent the same as in previous rounds. Diameter, 9 to 9¼ inches. No fringe. Four fine but apparently through cracks, one down, one up, one to right, and one to left, at about equal distances apart. These were subsequently opened to wide through cracks; the one down, 20 inches long to bottom of plate; that to right, 17 inches long to edge of plate; the one up, 35 inches long to crack from No. 1 indent; the one to left, 15 inches long to No. 3 indent. There appears to be little difference in the effects of the above four rounds.

"*Fifth Round.*—Projectile, Holtzer No. 38. Point of impact, 1½ inch above to left of centre of plate. Shell broke up, but head penetrated plate. Head apparently entire. End of powder chamber 7⅝ inches beyond face of plate. This would bring point 14·8 inches beyond face of plate (4·8 inches beyond rear face), and base 2¼ inches in front of face of plate. The greater part of base picked up near target. Diameter of indent at surface of plate, 7¾ inches, decreasing to 6½ inches at 3 inches from face.

No fringe. More of the plate scaled off in the neighbourhood of the indent than in previous rounds. Small portions of the plate scaled off (thickness of scale, $\frac{1}{8}$ inch) about 8 inches from indent. Through crack, 16 inches long to No. 2 impact. Through crack, 19 inches long to No. 4 impact. Surface crack, 7 inches long to left. Surface crack, 16 inches long upward and to right. Surface crack, 3 inches long down. All old cracks widened.

"*Sixth Round.*—Projectile, Carpenter 205 C. Point of impact, $1\frac{1}{8}$ inch above. 13 inches to right of centre of plate. Shell broke up badly. Character of the indent much the same as in the first four rounds, but I judge the point to have reached a less depth. Through crack, 9 inches long to No. 5 indent. Partially through crack, 17 inches long to crack from No. 1 indent. Six short radial cracks. Saw cracks, 20 inches long below the indent. Old cracks much opened.

"A glance at the Harvey plate after the fifth or sixth round, and at the Schneider steel plates, the same make without treatment, clearly shows the effect of the latter. Its face has been thoroughly hardened, the only projectile which actually entered the plate being that used in the fifth round. The same impact developed peculiar flaking. This is attributed by those interested to a blister at that particular point, which prevented the effect of the treatment from entering as deep as usual. That it is entirely local is fully shown by the absence of the same effect at other impacts. The trial has demonstrated that the extremely hard face produced develops no tendency to separate from the softer back. It is to be noted, also, that, although the cracks produced were through cracks, not one part of the plate fell to the ground.

"We understand that the Secretary of the Navy has signed a contract for the treatment by the Harvey process of the armour plate to be used for our men-of-war, providing a further test prove satisfactory."

Ballistic Resistance.

After many years of study and trial and expenditure, there are as many opinions as to what ballistic resistance means as there are manufacturers of plates and officers who have witnessed the

tests, and yet there is not one definition that can be accepted as governing, regulating, and defining ballistic resistance. This is manifest from the following variable acts and opinions, which are quoted only to emphasise the point I wish to make—namely, the absence of any concurrence of opinion regarding this pre-eminently important characteristic.

Under the claim of the superiority of the nickel-steel plate the Secretary of the Navy secured an appropriation of $1,000,000 for the purchase of nickel matte. He states in his annual report for 1890 that "the vice of the all-steel armour is its tendency to crack. This liability to crack at shock or perforation seems to be removed by an alloy of about 5 per cent. of nickel. The mixture enhances to a noticeable degree the qualities of elastic limit and tensile strength, leaving the percentage of elongation at a figure which makes cracking almost impossible. These qualities are precisely those necessary in armour plate. The nickel plate, though slightly more penetrable, remained absolutely uncracked."

It is currently reported that the Department has made a conditional contract with a company for the treatment in which cracking is the dominant feature, although penetration is greatly decreased and the destruction to the projectiles very great. Subsequent investigation has shown in transverse specimens taken from the nickel-steel plate a very radical decrease in the percentage of elongation, and Mr. Barba has pointed out that the superiority of the nickel-steel plate was as much, if not more, due to the great experience in treatment and manipulation as to the percentage of nickel alloy.

When the Annapolis Board placed the nickel-steel plate first in the order of merit, its superiority and toughness were attributed to the percentage of nickel alone. Mr. Barba has said that the value of nickel was that it increased "notably the degree of hardness" (which will probably increase the tendency to crack), and that he "did not see the necessity of seeking so earnestly the suppression of cracks, since they did not exercise any influence upon perforation."

Mr. Barba, it appears, considers fracture a very secondary matter to perforation, a fact that should place the Annapolis all-

steel plate ahead of the nickel-steel, which had as high as 30 per cent. greater penetration.

It was formerly insisted that through cracks should not be allowed, but when they do not expose the supporting structure much will be gained as to penetration because of the greater resistance of the steel.

At the Annapolis trials great credit was taken for the toughness of the nickel-steel plate, although it was more penetrative, but the acquisition of non-cracking qualities thought to have been proved by this example received a check when the Schneider nickel-steel was tested at Ochta.

With the probable employment of high explosives, perforation is a serious matter. Although the dimensions of the explosive chambers of shells were decreased in order to obtain a form of projectile possessing the power to perforate, now that this has been secured, the tendency will be to seek greater destruction after perforation by the use of high explosives. If this be accomplished resistance against perforation will become the prominent quality to be secured.

Even from the standpoint of admitting (which I do not) the inferiority of all-steel to compound plates in the resistance of *common* shells, the best plate must keep out every form of projectile, no matter how small may be the percentage of armour-piercers when compared with the common or less formidable shell.

If compound plates should behave better under the attack of common shell than all-steel (provided the all-steel is not penetrated and does not fall off), but do not offer so great resistance to armour-piercers as the all-steel, they cannot be accepted as the equal of all-steel.

If there is even a possibility of a ship being attacked at the highest velocity with which experimental plates are now struck, this condition should undoubtedly enter into the consideration of the efficiency of the plate.

Ships must be protected to meet the exceptional as well as the ordinary conditions of service, for it is the unexpected that always happens. Because ships may fight at 1500 or 2000 yards (or even at greater distances), that is no argument for protecting them *only* for that distance. Mr. White aptly compares the

condition of attack and defence when he says: "It it but fair to remember that in a battle of the plates and the guns the attack was free and variable, while defence was not. The attack might say, We have to deal with a different kind of armour, and we will use a form of projectile more suitable to destroy it."

In seeking the highest development of armour protection, provision must be made for keeping out everything, for the ablest commanders will have a variety of weapons at their disposal for attack, and will use such as will most readily overcome the kind of defence with which they may fall in.

Mr. Thomas Vickers, whose opinions upon technical steel manufacture retain the high position so long accorded them, in following the medium course between toughness and hardness has secured a well-earned success, and has earned the reward of being to-day the first British manufacturer to receive from the Admiralty an order for all-steel armour for the belt of an important battleship.

As my faith in, and recommendations of, steel armour have never been for a moment weakened from the commencement of my investigations, the present state of the art is extremely satisfactory to me. My conclusions may be briefly stated. All open competitive trials have shown the *all-steel* to be superior; the last test at Annapolis conspicuously so.

My objections to compound iron and steel armour have been fully stated in previous papers, and no progress in its manufacture has as yet removed any of the objections I have set forth.

The iron back is of no value except for its mass, as it is not expected to assist much in keeping out the shot after the steel face is flaked off; this want of "power of the face plate to adhere to the foundation," and the "cost (sacrifice) of a junction of the two metals" to obtain the hard steel face, constitute prominent weakness of this system.

Captain Tressider, late of the Royal Engineers, and now a representative of Messrs. John Brown & Co. of Sheffield, makes a definite distinction between the resisting powers of all-steel and British compound armour in his discussion of the results of the Ochta (Russian) trials of November 1890. Speaking of the velocities, he says: "The first two shots were at 1900 feet per

second, and other three at 2100 feet. The latter was just up to the penetration of the compound armour and just below the penetration of steel. Another 100 feet per second would have brought the penetration up to that of steel armour."

From a glance at these opinions, it would seem that the components of ballistic resistance will all, or nearly all, be found among the following: Perforation, penetration, deformation of the back of the plate, uniformity, through cracks, detachment from the supporting structure, injury to the supporting structure, and the shattering effects of heavy projectiles.

In the order of merit, those plates should be entitled to the first place which show the greatest resistance against perforation, have the least penetration, do not expose the supporting structure, break up the projectiles, and (since all plates cannot be tested ballistically) can be manufactured so as to secure the most uniform results.

I still advocate the compound steel plate which I suggested in 1886, and I hope soon to be able to state that it has been brought to successful issue by experiments that are now progressing. The all-steel plates, manufactured by Bethlehem, possess a very high ballistic resistance, as shown in the accompanying drawings and description of an 11½-inch experimental plate, tested in January last at Annapolis, with the same 6-inch gun that was employed in the September trials. The excellent condition of the back of the plate, the good elongation and uniformity are particularly noticeable, and illustrate the progress that Bethlehem has already accomplished.

Bethlehem Armour.

Information trial (ballistic test) of an 11½-inch Bethlehem press-forged steel plate, Annapolis Proving Ground, January 20, 1891.

Weather—cloudy, damp. Temperature, 40° F. Firing commenced 10 A.M.

Dimensions of plate, 6 feet by 4 feet 6 inches by 11½ inches.

It was secured to the backing with 4 bolts 2¾ inches diameter. The backing (36-inch oak) employed was the same (repaired) as that used for the Creusot nickel-steel plate at the Annapolis trials of September 18 and 22, 1890.

It must be noted that there were but four securing bolts, and that there were no side, top, and bottom plates.

Plate.	No. of Bolts.	Dia. of Bolts.	Total Bolt Cross section.	Weight of Plate.		Bolt section per ton of steel.
				Lbs.	Tons.	
Steel, press forged; oil tempered .	4	2¾	23·76	12,782	57·06	4·164

The gun used was the 6-inch B.L.R., Mark III., 35 calibres long, employed at the Annapolis trials previously mentioned. It was fabricated at the Washington Gun Factory, and made of Bethlehem steel.

The powder was brown prismatic, manufactured by Messrs. Du Pont.

The projectiles (Fig. 5) were all Holtzer 6-inch armour-piercing shell, with ogival of two calibres radius, and were brought up to the standard weight of 100 lbs. by filling them with sand and lead.

The firing was at a slight depression.

The pointing was done by means of central cross hair sights in the axis of the bore. The gun was fired by means of electric primers and dynamo.

Velocities were taken for the first and second rounds. For the third it was assumed to be the same as for the second.

To meet the requirements of the specifications there were required *—

Striking velocity	2097 feet.
Striking energy	3048 „ T.

Lieut. Commander Dayton was limited by the Bureau to a pressure of 15 T. This, and the low temperature, prevented his securing the required velocity and consequent energy.

The offer to warm the plate was declined.

ROUND 1. PLATE 1.

Muzzle velocity	2057 feet.
Striking velocity	2032 „
Striking energy	2862 „ T.
Powder charge	48 lbs.

* Calculations of Lieut. C. A. Stone, Bureau of Ordnance.

The point of impact was 18 inches from the top, and an equal distance from the two sides. The projectile penetrated to a depth of 12⅜ inches, and rebounded entire to a distance of 25 feet in front; it was shortened ·1 inch. A front bulge was raised 11 inches in diameter and 1 inch high, with a uniform fringe projecting ⅞ inch; or height of fringe from the face of plate 1⅞ inch. Six short radial cracks were developed in the bulge. One small piece of fringe scaled off. The surface of the shot-hole was smooth and regular—diameter of entrance 6 inches. The backing and bolts undisturbed.

ROUND 2. FIG. 2.

Muzzle velocity	2091 feet.
Striking velocity	2065 „
Striking energy	2956 „ T.
Powder charge	48½ lbs.
Pressure	14·55 T.

The point of impact was 25½ inches from the right side, and 19·81 inches from the bottom. The projectile penetrated to a depth of 13 inches, and rebounded entire to a distance of 35 feet directly in front; it was shortened ·1 inch. A front bulge was raised 12 inches in diameter and 1 inch high, with a uniform fringe projecting ⅞ inch; or height of fringe from face of plate 1⅞ inches. Eight short radial cracks were developed in the bulge. The surface of the shot-hole was smooth and regular—diameter of entrance 6 inches. The backing and bolts undisturbed.

ROUND 3. FIG. 3.

Muzzle velocity	2091 feet.
Striking velocity	1065 „
Striking energy	2956 „ T.
Powder charge	48½ lbs.

The point of impact was 25½ inches from the left side and 17·81 inches from the bottom. The projectile penetrated to a depth of 13⅜ inches, and rebounded 25 feet in front of the target, breaking transversely into two large pieces at the beginning of the ogive; the fracture showed a very uniform fine grain.

A front bulge was raised 12 inches in diameter and 1 inch high, with a uniform fringe projecting 1 inch; or height of fringe from face of plate 2 inches. One through crack developed below shot-hole extending to bottom edge of plate, but did not expose backing.

Fracture uniform fine grain. A fine surface crack connected hole No. 3 with hole No. 1, and a surface hair crack extended from hole No. 1 to top of plate. Four short radial cracks also developed. The surface of the shot-hole was smooth and regular, and showed star-shaped cracks at its inner extremity, just exposing the backing —diameter of entrance 6 inches. The backing and bolts undisturbed, but plate very slightly started from backing.

January 21, the plate was removed from the backing. An examination of its back (Fig. 4) showed it to be in excellent condition. The back bulges were uniformly curved, with no indication of fracture or cracks around their circumference.

Round 1.—Back bulge 11 inches diameter, $1\frac{3}{8}$ inch high.

Round 2.—Back bulge 12 inches diameter, $1\frac{1}{2}$ inch high. Faint hair crack $2\frac{1}{4}$ inches in centre of bulge.

Round 3.—Back bulge 12 inches diameter, $1\frac{13}{16}$ inches high. Star-shaped cracks with radii from $1\frac{1}{2}$ to 3 inches—one through crack below shot-hole, extending to bottom edge of plate, one fine hair crack 6 inches long half-way between holes 1 and 3.

The indents in backing conformed to back bulges of plate. Backing not splintered.

With the exception of one small piece of fringe, which scaled off in the first round, no particle of the plate was detached.

See Fig. 6 for graphic description of target, appearance of plate after each round, and the back of plate after removal from backing.

W. H. JAQUES,
Ordnance Engineer.

It has been stated so frequently that the British compound plates were not subjected to rigid inspection during and subsequent to manufacture, that I have been very much interested in the statement of the Chief Constructor that the Admiralty practice was to carefully inspect the manufacture, and to test physically and chemically all armour plates that have entered into recent British warship construction. It would be still more interesting to learn what those requirements are, in order that they may be compared with the following United States practice, which, it will be seen, is very rigid and exacting.

TESTS.

At least two chemical analyses shall be made, by and at the expense of the contractor, from each ingot (one from each end), and records thereof shall be kept by him.

From the discarded pieces, and at points as near as practicable to the portion of the ingot from which the plate is to be made, shall be taken four test-bars, two from each end, each of which will be reduced, by forging, until the ratio between its original and final forged cross section equals $2\frac{3}{4}$ inches.

The specimens turned from these bars must be cylindrical in form between measuring points, which will be two inches apart, and the diameter of the cylinder will be one-half inch. They may be annealed, but not tempered, and when physically tested they must not show a less mean tensile strength on the original cross-section than 82,000 pounds per square inch, nor a less mean final elongation than 20 per cent. The variations from the mean must not be large.

After the ends of an ingot are discarded (as above) its weight must be at least 34 per cent. in excess of that of the trimmed and finished plate. The ingot shall be forged or rolled as much as the best practice requires, but in no case shall the ratio between the mean cross-section of the ingot and that of the trimmed and finished plate be less than three. During the process of reduction, as above, no metal shall be cut off except such as will clearly have no further beneficial effect on the working of the metal which is to compose the finished plate.

After the plates have been subjected to all the treatment they are to receive, and are otherwise entirely finished (except bolt-holes), tests will be made from them for the purpose of exhibiting both absolute and relative quality, first in those parts of the same plate which have received similar treatment, and second between all the plates of a group. For this purpose four specimens will be taken from the bolt-holes in the rear face of each plate.

BALLISTIC TESTS.

The ballistic test is the chief one, and the object of all the other tests of ingots and plates is to ensure, so far as possible,

that the remaining plates of a group are capable of standing as severe a test as that to which the test-plate has been subjected, and the conformity required among the plates of a group will be only such as may be necessary for this purpose.

The plate from each group intended for the ballistic test will be selected by the Department at any stage of the manufacture, after the group that includes it is forged, cut virtually to dimensions, shaped, and completely treated. It will be prepared for test at the expense of the contractor. The ends must be trued.

The plate will be bolted against a substantial wooden backing 36 inches thick. If the plate is tapered, or otherwise intentionally varied in thickness, the backing will be maintained of full depth behind the thinnest part, and will be faced off behind the other parts in such a way as to bring the front face of the plate vertical. The whole structure will be braced from the rear, and the bolts will be of the same kind as are to be used on shipboard.

Near the middle region of the plate there will be marked three points of proposed impact, arranged so as to form an equilateral triangle, each side being in length 3½ times the diameter of the shot to be used in the test.

For plates of constant thickness one apex of the triangle will be placed upwards, the other two being disposed below on a horizontal line.

For plates tapering in thickness, two of the proposed points of impact will be arranged in the thinner part on a line parallel to that upon which the taper commences, and, when practicable, at least one calibre from it. The third point will be placed on the thicker part.

If the distance from any apex of the triangle (as laid out) to the edge of the plate is less than 1½ calibre of the projectile, the Department may arrange the proposed points of impact in a straight line, near the middle line of the plate, and preferably in its thin part; the space between the proposed points of impact must remain at 3½ calibres. In such circumstances the centre shot shall be delivered last.

The rules regarding positions of the points of proposed impact are intended as aids to conducting the test with regularity. The

guns will be aimed for these points, but no allowance will be made for the ordinary errors inherent to artillery fire.

When the proposed point of impact falls upon the tapered part of the test-plate, the thickness for which the velocity is to be calculated shall be measured at the thinnest point on the circumference of a circle described around the proposed point of impact, with a radius equal to the semi-diameter of the shot.

The calibres of guns used against plates will be as near as conveniently practicable to the thickness of the plate at the point of impact, but said calibres shall be so restricted that when the gun is fired with service weight of shot, a velocity of at least 1200 feet per second (at impact) will be necessary in order to develop the projectile energy required by the formula.

The velocity of the projectile will be such as gives by calculation sufficient energy to cause the projectile to just pass entirely through a wrought-iron plate and its wooden backing; the wrought-iron plate being supposed to be equal in thickness to the test-plate and the backing to be 36 inches thick; the latter subject to the reduction hereinbefore mentioned for plates of varying thickness.

The velocity will be calculated by the following well-known formula of Gavre, in which the projectile is supposed not to experience any change of form while passing into or through the target. The same charge of powder being used, the actual striking velocity will vary from that obtained by calculation within the usual limits:

$$\frac{p}{a}V^2 = 3507\ E^2 + 2265464 e^{1 \cdot 4}$$

p = the weight of the projectile in pounds.
a = the diameter of the projectile in inches.
V = the velocity, at impact, of the projectile, in feet per second.
E = the thickness of the backing in inches.
e = the thickness of the armour plate in inches.

The following table shows the velocity and energy (calculated by the above formula) that would be used in firing against plates of different thickness, employing certain guns. These guns will not necessarily be used, and the table is only intended to illustrate the effect of the formula upon the conditions of a test:—

Target.		Gun with service-shot.	Value of p.	Value of a.	Velocity at impact.	Total energy at impact.
Plate.	Backing.					
Inches.	Inches.		Lbs.	Inches.	Feet-seconds.	Foot-tons.
6	36	6-inch B. L. R.	100	5·96	1,389	1,337
7	36	6-inch B. L. R.	100	5·96	1,528	1,619
8	36	8-inch B. L. R.	250	7·96	1,213	2,550
9	36	8-inch B. L. R.	250	7·96	1,308	2,966
10	36	8-inch B. L. R.	250	7·96	1,399	3,390
11	30	8-inch B. L. R.	250	7·96	1,489	3,839
12	36	10-inch B. L. R.	500	9·96	1,247	5,386
13	36	10-inch B. L. R.	500	9·96	1,315	5.987
14	36	10-inch B. L. R.	500	9·96	1,381	6,608
15	36	12-inch B. L. R.	850	11·96	1,215	8,699
16	36	12-inch B. L. R.	850	11·96	1,269	9,71Ↄ
17	36	12-inch B. L. R.	850	11·96	1,332	10,454
18	36	12-inch B. L. R.	850	11·96	1,374	11,124
19	36	12-inch B. L. R.	850	11·96	1,425	11.965
20	36	12-inch B. L. R.	850	11·96	1,476	12,837

A steel projectile (of the best quality and manufacture, as determined by the Department) will be fired at each of the three points of proposed impact, under the general conditions before described.

No projectile, nor any fragment of the plate, must get wholly through the plate and backing.

The plate must not break up, and pieces be displaced, so as to expose the backing, before the impact of the third shot; neither must very large cracks which expose the backing appear before the impact of the third shot.

After the first shot, if the contractor should so request, the following changes may be made:—

When serious cracks develop, running very near either or both of the proposed points of impact, these points may be shifted to such positions as the contractor may select, provided no point is placed more than 3½ calibres from the centre of impact of each of the preceding shots. The Inspector determines the character of the cracks.

Firing at a plate will be stopped whenever, in the opinion of the Inspector, the plate has demonstrated its incapacity to stand the full test.

If the temperature of the air, at the time of the test, is above

40° F., the test-plates may be warmed to not above 60°, on the request of the contractor, and at his risk and expense. If the temperature is below 40°, the Department will pay for the warming (if demanded), the risk remaining as before.

The Department shall have the right to keep agents or inspectors at the works who will have free acess to all parts thereof, and will be permitted to examine freely the raw material, to witness all the processes of manufacture, and to examine the contractor's records with reference to such matters.

All test-pieces, bars, and samples are to be cut and tested in presence of an Inspector, who will stamp and have the custody of each. The Inspector may himself make the tests should he so desire, and the contractor is to afford him the necessary facilities and assistance for so doing.

Plates not much curved may be dropped on a suitable iron plate from a height of one yard, in order to test for brittleness, and to develop cracks.

If a delivered plate is rejected, the cost of transportation of the new one to the point of rejection of the old one must be paid by the contractor.

Plates that show cracks within six months after being fastened on the ship must be replaced by the contractor.

Deck-Armour—Gun-Shields.

All rolled armour plates for deflective decks, light gun-shields, and similar purposes, will be made of the best material, and will be oil-tempered and annealed. They will be subjected to the following test for acceptance: Two specimens will be taken from each heat of deck-armour, these must show not less than 85,000 pounds tensile strength and 20 per cent. elongation. Two specimens will be taken from each gun-shield; these must show not less than 95,000 pounds tensile strength, and 15 per cent. elongation.

Specimen bars will be 2 inches between measuring points, and have a diameter of half-inch.

The plates must be free from defects of all kinds which lessen their effective resistance and value.

There are so many makers of armour now in the field that some more definite nomenclature than *all-steel* and *compound* must be adopted, as these terms are not sufficiently definite to cover the numerous types. We already have Schneider metal, Terni metal, Kolpino metal, Cammell (Wilson) metal, Brown (Ellis) metal, Bethlehem metal, Harvey metal, Dillengen metal, Marrell metal, Vickers metal, Chatillon et Commentry metal, St. Chamond metal, with others entering the race, all seeking first place.

Before concluding my remarks on armour I desire here to correct the impression given by Mr. Evrard in his letters to *Le Genie Civil*, that Messrs. Schneider & Co. are installing at Bethlehem a plant for the manufacture of steel armour. This is not the case to the extent implied. Bethlehem has had free consultation with Creusot, but has built its own plant, which in many points differs radically from Creusot.

GUNS.

Great progress has been made in the heavy gun supply for both the army and the navy. The situation of the former cannot be better described than in the words of Captain Rogers Birnie, United States Army, in his new edition of "Gun Making in the United States:" * "The surroundings of the question of coast-defence to-day, and as they appeared three years since, are in striking and happy contrast. Then we were appealing to an only half-awakened public sentiment, and striving to prove that the time was ripe to begin, and now we are in the midst of a busy scene of action. No longer are we called upon to repress the sigh of envy at the happy progress of the navy in building its ships and guns. The opportunity is now afforded the army to do its part, and prepare the solid works of coast defence which will stand as the bulwark of our harbours."

The data relating to the army's progress has been taken from this excellent work. Contracts have been concluded with domestic manufacturers for the steel forgings for 112 field, siege, and sea-coast steel guns; the manufacture of 11 8-inch steel guns; and of 73 12-inch sea-coast mortars. Some of these have already been

* "Gun Making in the United States," by Captain Rogers Birnie, U.S.A. *Journal of the Military Service Institution*, April 1891.

fabricated into cannon at the Watervliet Gun Factory; the remainder will be completed at this factory, with the exception of eleven which the West Point Foundry has engaged to build. Composite mortars are also being supplied by the South Boston Iron Works and Builder's Iron Foundry.

The manufacture of Hotchkiss' revolving cannon and Driggs & Hotchkiss' rapid-fire guns continues.

The table on page 34 is also taken from "Birnie's Gun Making."

The guns for the navy are being turned out very rapidly, the Bethlehem Company having delivered some ninety complete sets of forgings, including four sets of 12-inch calibre. All of these guns are being fabricated at the Washington Gun Factory.

In his annual report for the year 1890, Commodore Folger, the present Chief of Bureau, states that the general system of manufacture and construction developed by his predecessor in the Bureau, Commodore Montgomery Sicard, U.S.N., has been adhered to, and it should be appreciated that it is due to his able, wise, and painstaking efforts that the Department is at present in a position to proceed with confidence and energy with the rapid and efficient armament of the modern war vessels, the construction of which has been authorised by legislation.

The following table gives the number of sets of forgings thus far ordered, the number of guns completed to October 15, 1890, and the number in course of construction at the Washington Gun Factory:—

Calibre.	Nr. of sets of forgings ordered.	No. of guns completed.	No. in course of construction. forgings for which have been delivered.
4-inch . .	35	4	12
5-inch . .	4	2	—
6-inch . .	128	77	25
8-inch . .	35	15	2
10-inch . .	25	4	3
12-inch . .	8	—	—
13-inch . .	12	—	—

United States Army Breech-Loading Rifled Ordnance, 1890.

Calibres.	Weight.	Total length.	Length of bore.	Charge.		Powder pressure.	Initial velocity.	Muzzle energy.	Number of guns, &c.	
				Powder.	Projectile.				Ordered.	Completed
	Pounds.	Feet.	Calibres.	Pounds.	Pounds.	Tons.	Feet.	Ft.-tons.		
Mountain and Field Artillery.										
3-inch Mountain gun, steel	218	3·9	14·0	0·88	12·0	6·5	870·0	63·0	1	1
3·2-inch Light field gun, steel	829	7·56	26·0	3·75	13·5	15·0	1675·0	263·0	100	75
3·6-inch Field gun, steel	1181	7·56	23·0	4·50	20·0	16·0	1554·0	335·0	1*	1
3·6-inch Field mortar, steel	244	2·75	5·25	1·00	20·0	8·0	650·0	58·0	1§	1
Siege Artillery.										
5-inch guns, steel	3660	12·15	27·0	12·50	45·0	16·0	1830·0	1000·0	11	1
7-inch howitzer, steel	3710	8·06	12·0	9·75	105·0	12·5	1085·0	857·0	11	1
Sea-coast Artillery.	Tons.									
8-inch gun, steel	14·5	23·21	32·0	130·0	300·0	16·5	1935·0	7787·0	25	2
†10-inch gun "	30·0	30·60	34·0	256·0	575·0	16·5	1940·0	15000·0	24	1
12-inch gun "	52·0	36·66	34·0	440·0	1000·0	16·5	1940·0	26000·0	16	—
12-inch mortar, cast-iron, steel hooped	14·25	10·75	9·0	80·0	630·0	12·5	1152·0	5796·0	74	1
‡12-inch mortar, steel	13·0	11·76	10·0	100·0	800·0	16·0	1150·0	7334·0	1	—

* Orders for 24 guns await completion of tests of type gun. § Orders for 16 mortars await completion of tests of type mortar. † Plate 6. ‡ Plate 7.

The annexed table of naval ordnance, just issued by Captain Birnie in the work already referred to, indicates the progress that

has been made by the Navy in providing modern steel b eech-loading rifles:

UNITED STATES NAVAL BREECH-LOADING RIFLE GUNS, 1890.

Calibres.	Weight.	Total length.	Length of bore.	Charge.		Powder pressure.	Initial velocity.	Muzzle Energy.	Number of guns.	
				Powder.	Projectile.				Ordered.	Completed
	Tons.	Feet.	Calibres.	Pounds.	Pounds.	Tons.	Feet.	Ft.-tons.		
4-inch R. F. & B. L. R. Mark I., steel	1·5	13·7	40·0	14·0	33·0		2000·0	915·0	35	4
5-inch R. F., steel	3·1	17·4	40·0	30·0	50·0		2250·0	1754·0	2	—
5-inch, Mark I., steel . . .	2·8	13·5	30·0	30·0	60·0		2000·0	1664·7	—	2
6-inch, Marks I., II. and III.. steel .	4·8 4·9	15·8 16·3	30·0	47·0 50·0	100·0		2000·0	2774·0	125	76
6-inch (35 calibres), steel . .	5·2	18·8	35·0	47·0	100·0		2080·0	3000·0	1	1
6-inch (40 calibres), steel . .	6·0	21·3	40·0	47·0	100·0	15·0	2150·0	3204·0	2	—
8-inch, Marks I. and II., steel .	12·3 13·0	21·5	30·0	115·0	250·0		2000·0	6734·0	35	15*
8-inch, Mark III., steel . . .	13·1	27·4	35·0	115·0	250·0		2080·0	7498·0		
10-inch, Marks I. and II. (30 cal.), steel	25·1 25·7	27·4	30·0	240·0	500·0		2000·0	13870·0	26	4
10-inch, Marks I. and II. (35 cal.), steel	27·1 28·2	30·5 31·2	35·0	240·0	500·0		2080·0 2100·0	15000·0 15285·0		
12-inch, steel	45·2	36·8	35·0	425·0	850·0		2100·0	25985·0	8	—
13-inch, steel	60·5	40·0	35·0	550·0	1100·0		2100·0	32862·0	12	—

* Including six guns of Mark III. An 8-inch gun of 40 calibres length has been designed.

The cause of greatest anxiety to the gunmaker is the erosion of the bore by powder-products.

This subject is no less prominent to-day than when we listened to Sir Frederick Abel's paper in November 1886, and its probable disastrous effects in ordnance where such enormous powder charges are employed still causes hesitation on the part of artillerists to recommend the construction of the heaviest calibres, although their smashing and racking powers are so requisite against thick armour. Since that date I have witnessed many experiments, both chemical and mechanical, which have strengthened the opinion I then expressed that the amount of work and treatment were more to be looked to as the determining agent than chemistry, and that the solution of it would be found in the mechanical field. This difficulty will probably be best surmounted by carbonising or cementing the inner surface or bore, which should be highly polished or hardened by mechanical mandreling in order to secure the smoothness needed to prevent the punishment of the bore by heavy charges. To secure these results, however, no *less* importance must be given to the chemistry of gun steel, for never before has so much attention and weight been given to the importance of its chemical composition.

The failure of the British 110-ton guns does not convey to my mind any reflection upon the usefulness of such large calibres.

At the Institute's autumn meeting of 1886, Mr. Charles Markham said, "Rightly or wrongly, the strong feeling generally prevailed that the manufacture of our (British) guns was not worthy of the mechanical reputation of the country."

I deem the failures mechanical only, and if the guns are constructed in a manner equal to many of the modern marine engines that have been built in Great Britain, they will be equally efficient and serviceable. The efficient service of these guns must not be compared directly with the number of rounds that can be fired from smaller calibres, but rather from the effective amount of destructive work that can be got out of them.

The tendency to substitute for the larger armament an increased number of guns of reduced calibre, notably of the rapid-fire class, will no doubt soon meet with a reaction because of the loss of that powerful element of destruction, the shattering and racking power

so necessary in combat with heavily-armoured ships. A mixed battery of large and small guns is no doubt the most useful compromise, for what is a ship to-day other than a compromise—in fact, a combination of compromises?

As directly bearing upon the question of the economical facility and quality of production, I present for comparison the specifications required by Great Britain and the United States, defining and governing the exhibits of gun steel. It is to be hoped that Dr. Anderson's predictions may prove true, that the Mechanical Engineers' Committee will discover some quicker method of learning the physical characteristics of steel than that now in vogue.

GREAT BRITAIN.

Tests to be Applied to Steel for Ordnance.

(*To be modified when larger Test Pieces are adopted.*)

Particulars of Specimens.

From Tubes.

Each end of forgings for tubes is to be made so much longer than is needed for the length of the finished tube as to afford sufficient metal to give from the annulus between the outside of the forging and the bore of the tube (or the bore of the chamber, as the case may be) the four specimens mentioned below, and also two spare specimens of similar dimensions, being six in all.

The specimens, if cut longitudinally, are to be so situated that their insides will be in line with the circumference of the bore, or of the chamber, as the case may be; and, if cut transversely, to be so situated that the middle of the length of each specimen shall be a tangent to the bore, or to the chamber, as the case may be.

From Breech-pieces or Jackets.

The end of the jacket or breech-piece which was nearest to the upper end of the original ingot is to be made so much longer than is needed for the length of the finished breech-piece or jacket as to afford sufficient metal to give from the annulus between the outside of the forging and the bore of the breech-piece or jacket the four specimens required for the testing, and also two spare

specimens of similar dimensions, being six in all; the specimens to be cut in the manner laid down for those from tubes.

From Hoops.

Hoops are to be tested in the same manner as breech-pieces or jackets, except that the specimens are to be cut transversely only; but in cases where several hoops have been forged from one ingot, it will be only necessary to cut a ring from one end of one of the hoops, such ring being taken from the upper end of that hoop which was nearest to the upper part of the ingot.

In cases of hoops not more than 36 inches wide it will suffice if one set of test samples be taken from either end of the hoop. The end to be selected by the testing officer.

Dimensions of Specimens and Temperature at which they are to be "Tempered."

Tensile Specimens.

Two specimens are to be tested "tempered."

Each specimen is to be cut in a parallel cylindrical form 1 inch in diameter and $4\frac{1}{2}$ inches long, is then to be heated to between 1350° and 1550° F. (a record of the actual temperature employed being kept for future information), and plunged into a bath of rape oil having an initial temperature of 65° F.

When cold, the specimen is to be turned to testing size.

The operative part of each specimen is to have, for a length of 2 inches, a uniform diameter of 0·533 inch. The enlarged ends of specimens are to be made of a form to suit the holders of the testing machine, and are to be united to the operative part by easy curves.

Bending Specimens.

Two specimens are to be tested "tempered."

Each specimen is to be cut to a width of 1·2 inch by a thickness of 0·825 inch. It should be tempered as above described for the tensile specimens, and be reduced to testing size when cold.

Each specimen is to be $4\frac{1}{2}$ inches long by $\frac{3}{4}$ inch wide by $\frac{3}{8}$ inch thick.

TESTS.

The whole of which are to be conducted cold.

Subject to clauses 1 and 2, the tensile specimens are to bear the following tests:—

Yielding Points, Tons per square inch.				Breaking Strain, Tons per square inch.				Elongation not less than per cent.
Not less than		Not more than		Not less than		Not more than		
22	to	33	...	33	to	45	...	17

The bending specimens are to be pressed flatways with a semi-circular ended presser through one or more suitable apertures, furnished or not furnished with anti-friction rollers, at the option of the contractors. This test is to be borne without the steel exhibiting any indication of fracture.

Diameter of Presser.	Width of Aperture.
1⅛ inch.	2⅝ inch.

1. In cases where the forging fails to bear the required tests at either or both ends after tempering (also with the allowance given by clause 2) at a temperature between the limits laid down in the specification, a fresh set of samples may be taken from such end or ends of the forging, and be tempered at a temperature to be selected by the maker, but not lower than 1350 degrees, nor higher than 1550 degrees, all the samples comprised in one set from one end of the forging being tempered at one temperature. If the fresh set of samples fulfil the conditions, the forging may be considered to have passed the tests. The particulars of the first and second tempering should be recorded for guidance in tempering the metal for the gun.

2. In cases where the samples from a forging have satisfied the tests for bending, elongation, and breaking, but exceed the superior limit of the yielding tests, the forging may be considered as having passed the tests.

3. The foregoing tests, being made for the benefit of the Government, and not for that of the contractors, shall not relieve them from any responsibility they would be under in the absence of such tests, and shall not prevent the rejection of the steel should it be otherwise unsatisfactory.

NAVY, UNITED STATES.

Forgings will be critically inspected for defects of soundness and workmanship. The records and facts as to their composition and treatment and all other matters affecting them will be considered, and they will be subjected to physical tests.

These tests are to be made on cylindrical specimens 2 inches long between measuring points, ½ inch in diameter. The specimens are to be taken from the forgings after final treatment transversely to the axis of the bore of the finished gun, and within the finished section prolonged. They are to be taken as near the finished piece as practicable, leaving sufficient metal for submitting additional test-bars in case of re-treatment.

Test-bars shall be cut and tests made under the supervision of an agent or inspector of the Department, who may make the tests personally if he should so desire. He will stamp and have the custody of each test-bar.

The following tables of specifications indicate certain limits of physical qualities that may be shown by tensile specimen, upon which the acceptance or rejection of forgings and castings will be based according to the rules given below:

TABLE 1.—6-inch and 8-inch guns.

	Tubes.			Jackets.		
	A.	B.	C.	A.	B.	C.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Tensile strength . .	80,000	72,000	70.000	85 000	76,500	74.000
Elastic limit . . .	38,000	34.000	33.000	40.000	36.000	34,000
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Elongation. . . .	22	20	12	20	18	12
Contraction of area .	35	20	15	30	20	15

TABLE 2.—10-inch and 12-inch guns.

	Tubes.			Jackets.		
	A.	B.	C.	A.	B.	C.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Tensile strength . .	80,000	72,000	70,000	85,000	76,500	74.000
Elastic limit . . .	38,000	34,000	33,000	40,000	36,000	34,000
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Elongation	20	18	12	18	15	10
Contraction of area .	30	20	15	30	20	12

TABLE 3.—For all calibres.

	Hoops.			Trunnion-bands.		
	A.	B.	C.	A.	B.	C.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Tensile strength . .	100,000	90,000	90,000	90,000	80,000	80,000
Elastic limit . . .	50,000	45,000	45,000	40,000	36,000	36,000
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Elongation	18	16	12	12	10	6
Contraction of area .	30	25	15	15	12	8

The contractor shall first present three specimens from each end of a tube or jacket, and from the end nearest the upper end of the ingot or casting of each hoop, plug, or trunnion-band.

The three specimens taken from either end of tubes or jackets shall be considered independently of those taken from the other end of the same piece.

In the tables below the columns A, B, and C refer to the corresponding columns in the tables of specifications, and the figures indicate the number of specimens which have shown characteristics equal to or above, in all particulars, those given in the corresponding column of the tables of specifications.

TABLE 5.

A.	B.	C.	
3	—	—	If the results obtained from the first three specimens taken form any of these combinations, the forging or casting will be accepted. If they do not form one of these combinations, and if no one of them fails below column C, two more specimens will be taken, and all five specimens considered according to Table 6.
2	1	—	
1	2	—	
—	3	—	

TABLE 6.

A.	B.	C.	
3	—	2	If the results obtained from the five specimens form any of these combinations, the forging or casting will be accepted. If they do not form one of these combinations, and if no one of them falls below column C, two more specimens will be taken, and all seven specimens considered according to Table 7.
2	1	2	
2	2	1	
1	2	2	
1	3	1	

TABLE 7.

A.	B.	C.	
4	—	3	If the results obtained from the seven specimens form any of these combinations, the forging or casting will be accepted. If they do not form any of these combinations, the forging or casting may be rejected, unless there remains sufficient metal for additional specimens, in which case the contractor may re-treat it if he considers it capable of improvement by that means.
3	1	3	
2	2	3	
2	3	2	
1	4	2	

If, in making the above tests, one specimen falls below column C, the contractor may take two more specimens from the near vicinity of the spot from which the failing specimen came. One of these specimens must give results above column B and the other above column C, and the average of the results of the two specimens will be taken to represent the failing bar in considering the acceptance or rejection of the forging or casting, according to the preceding tables.

After a piece is cut or otherwise detached from a forging, no specimen from the piece will be considered if the latter has received any treatment after being detached as aforesaid.

If during powder proof after the completion of a gun, any forging therein shall fail on account of the presence of flaws, slag, cavities, or foreign substances in number or quantity serious enough to be clearly the sole cause of such failure, the foregoing shall be replaced by the contractor. The proof-rounds to which this rule applies shall not exceed five. Forgings are not *finally accepted* until they have borne this test.

ARMY, UNITED STATES.

For the army the manufacture of the material is required to be open to inspection in all its details, and complete information is exacted of all chemical and mechanical work, but somewhat different tests are required, the principal specifications of which will be found in the following tables:—

For Tubes and Jackets.

Number, Form, and Position of Test Specimens.

The stem of all test specimens shall, if possible, be taken within the finished interior and exterior surfaces of the piece prolonged.

Tangential test specimens shall be furnished from each tube and jacket as specified in the following table, No. I.:—

Table No. I.

Calibre of Cannon.	Designation of Piece.	Kind of Test Specimen.	No. of Specimens from— Breech End.	No. of Specimens from— Muzzle End.	Size of Specimens. Length of Stem.	Size of Specimens. Diameter of Stem.	Minimum Distance of Axis from end of Forging.
					Inches.	Inches.	Inches.
Field-cannon of all calibres.	Tube.	Tensile.	2	2	2·0	0·505	1·15
	Jacket.	"	2 or	2	2·0	0·505	1·15
Siege-cannon of all calibres.	Tube.	"	2	2	3·0	0·564	1·25
	Jacket.	"	3	3	3·0	0·564	1·25
Sea-coast cannon of 8 in. cal. and upward to 12 in. cal.	Tube.	"	3	3	3·0	0·564	1·50
	Jacket.	"	4	4	3·0	0·564	1·50
Sea-coast cannon of 12 inches calibre and over.	Tube.	"	4	4	3·0	0·564	1·50
	Jacket.	"	4	4	3·0	0·564	1·50

All with screw-ends as required.

9. *Physical Qualities.*

Each of the test specimens should show the physical qualities given in the following table, No. II., which the manufacturer shall aim to obtain:—

TABLE NO. II.

Calibre of Cannon.	Designation of Piece.	Elastic Limit.	Tensile Strength.	Elongation after Rupture.
		Lbs. per Sq. inch.	Lbs. per Sq. Inch.	Per cent.
Field-cannon of all calibres .	Tube. Jacket.	46,000 50,000	86,000 93,000	22·0 19·0
Siege cannon of all calibres .	Tube. Jacket.	46,000 50,000	86,000 93,000	20·0 18·0
Sea-coast cannon of 8-inch calibre	Tube. Jacket.	46,000 50,000	86,000 93,000	19·0 17·0
Sea-coast cannon of 10-inch calibre and over . . .	Tube. Jacket.	46,000 48,000	86,000 90,000	19·0 17·0

The forgings shall, however, be accepted as to physical qualities, provided no one of the specimens shows results in any particular below the figures given in the following table, No. III. :

TABLE NO. III.

Calibre of Cannon.	Designation of Piece.	Elastic Limit.	Tensile Strength.	Elongation after Rupture.	Contraction of Area.
		Lbs. per Sq. inch.	Lbs. per Sq. Inch.	Per cent.	Per cent.
Field-cannon of all calibres	Tube. Jacket.	42,000 46,000	78,000 86,000	20·0 17·0	35·0 30·0
Siege-cannon of all calibres	Tube Jacket.	42,000 46,000	78,000 86,000	18·0 16·0	30·0 27·0
Sea-coast cannon of 8-inch calibre . .	Tube. Jacket.	42,000 46,000	78,000 85,000	17·0 16·0	30·0 27·0
Sea-coast cannon of 10-inch calibre and over	Tube. Jacket.	42,000 44,000	78,000 83,000	17·0 16·0	30·0 27·0

Except that for the calibres and pieces enumerated below one, and only one, specimen from each end may be, in any one particular, lower in its qualities than the figures given in table No. III., but must not be, in that particular, lower than the figures given in the following table, No. IV. :

TABLE NO. IV.

Calibre of Cannon.	Designation of Piece.	Elastic Limit.	Tensile Strength.	Elongation after Rupture.	Contraction of Area.
		Lbs. per Sq. Inch.	Lbs. per Sq. Inch	Per cent.	Per cent.
Sea-coast cannon of 8-inch calibre	Jacket.	44,000	83,000	14·0	22·0
Sea-coast cannon of 10-inch calibre and over.	Tube.	40,000	75,000	15 0	25·0
	Jacket.	42,000	80,000	13·5	20·0

In addition to the tensile tests prescribed, the tubes and jackets shall be submitted to a powder test, or percussive hydraulic test, if desired by the United States, with interior pressure a little (about 1000 pounds) less than their elastic resistance. No weakness or defect should be developed by these tests; and the manufacturers shall detach rings for mandril or initial tension tests when in special cases they are notified that such rings are desired.

FOR HOOPS.

Number, Position, and Form of Test Specimens.

The stem of all test specimens shall, if possible, be taken within the finished interior and exterior surfaces of the hoop prolonged.

Tangential test specimens shall be furnished from each trunnion hoop, as specified in the following table, No. V.:

TABLE NO. V.

Calibre of Cannon.	Number of Test Specimens.		Size of Specimens.		Minimum Distance of Axis from End of Hoop.
	Breech End.	Muzzle End.	Length of stem.	Diameter of Stem.	
			Inches.	Inches.	Inches.
Field-cannon of all calibres	2 o	r 2	2·0	0·505	1·15
Siege-cannon of all calibres	3 o	r 3	3·0	0·564	1·25
Sea-coast guns of 8-inches calibre and over	4 o	r 4	4·0	0·564	1·25
Mortars of 8-inches calibre and over . .	3 o	r 3	4·0	0·564	1·25

All with screw-ends as required.

Tangential test specimens shall be furnished from cylindrical hoops, as specified in the following table, No. VI.:

TABLE No. VI.

Rough-Finished Size of Hoops.	Number of Test Specimens. From Breech End.	From Nozzle End.	From Hoop.	Size of Specimen. Length of Stem.	Diameter of Stem.	Minimum Distance of Axis from end of Hoop.
				Inches.	Inches.	Inches.
Not more than 8″ inside diameter. Not more than 30″ long	—	—	1	2·0	0·505	1·15
Not more than 8″ inside diameter. More than 30″ long	1	1	—	2·0	0·505	1·15
More than 8″ inside diameter. Not more than 16″ inside diameter. Not more than 30″ long	—	—	2	3·0	0·564	1·25
More than 8″ inside diameter. Not more than 16″ inside diameter. More than 30″ long	2	2	—	3·0	0·564	1·25
More than 16″ inside diameter. Not more than 34″ inside diameter. Not more than 26″ long	—	—	3	4·0	0·564	1·25
More than 16″ inside diameter. Not more than 34″ inside diameter. More than 26″ long	3	3	—	4·0	0·564	1·25
More than 34″ inside diameter. Not more than 25″ long	—	—	4	4·0	0·564	1.25
More than 34″ inside diameter. More than 25″ long	4	4	—	4·0	0·564	1·25

All with screw-ends as required.

Physical Qualities.

The test specimens should show the mean physical qualities given in the following table, No. VII., as a minimum:

TABLE No. VII.

Size of Specimens. Length of Stem.	Diam'r of Stm.	Elastic Limit.	Tensile Strength.	Elongation after Rupture.
		FOR TRUNNION HOOPS.		
Inches.	Inches.	Pounds per square inch.	Pounds per square inch.	Per cent.
2·0	0·505	50,000	90,000	18·0
3·0	0·564	50,000	90,000	15·0
4·0	0·564	50,000	90,000	13·0
		FOR CYLINDRICAL HOOPS.		
2·0	0·505	50,000	90,000	18·0
3·0	0·564	53,000	93,000	15·0
4·0	0·564	53,000	93,000	13·0

Provided that for trunnion hoops one specimen may be, in any one particular, below the figures given in table No. VII., but not lower than 48,000 pounds per square inch in elastic limit, 88,000 pounds per square inch in tensile strength, or 1 per cent. less than given in elongation after rupture; and provided, further, that for cylindrical hoops, when three or four specimens are taken, one of these specimens, or one from each end, and no more, may be, in any one particular, below the figures given in table No. VII., but not lower than 50,000 pounds per square inch in elastic limit, 90,000 pounds per square inch in tensile strength, or 12 per cent. in elongation after rupture.

DRIGGS—SCHROEDER GUN.

As the development of this type of rapid-fire gun has been made solely in the United States, and as it is but entering its career of comparison in European countries, I append some prints (Figs. 8 and 9) showing the six-pounder gun, together with the details of its breech mechanism. The tested guns of this type have shown very satisfactory results, and the Company's orders and deliveries have already aggregated nearly 100 guns, distributed as follows:—

Constructed by Colt's Patent Fire-Arms Manufacturing Company—

15 1-pounder
10 3-pounders
40 6-pounders.

Building at Washington Navy Yard (navy)—

25 4-inch (36-pounders)
5 light 6-pounders (landing guns).

Delivered to the army—

1 6-pounder
1 3·2-inch field gun.

For British War Office—

1 3-pounder.

GUN FACTORIES.

Quoting some years ago from a paper on "Heavy Ordnance for National Defence," the situation was then described as follows:—

"That guns are sadly needed.

"That breech-loading chambered guns, from 5-inch to 17-inch calibre, and from 30 to 35 calibres in length, should be constructed on the principle of Mr. Vavasseur, of open-hearth steel made by the Whitworth process, and fitted with the interrupted-screw breech mechanism and polygroove or polygonal rifling.

"That we have no manufactories where the forged steel required for the parts of guns of more than 8-inch calibre can be produced, none where parts even for this calibre can be manufactured in sufficient quantities to meet the demand, and no gun factories where the heaviest guns adapted to modern warfare can be fabricated.

"That the guns should be manufactured in the United States of American material.

"That the tempered steel should be supplied by the private steel industries of the United States.

"That the guns should be fabricated—*i.e.*, the parts machined and assembled, and the guns finished and sighted—in two gun factories, to be established under the control of the Government, one for the army and one for the navy."

The result to-day is that nearly all of these conditions have been fulfilled. Steel for guns of any calibre can now be supplied by the private steel industries of the nation, while two splendid gun factories have been built and equipped where the steel parts can be quickly machined and assembled, and the guns rapidly fitted for service.

The Naval Gun Factory at Washington, D.C., has been in operation for a long time, and has already finished guns of all calibres up to and including 12 inches. The proofs of these guns have demonstrated them to be of most excellent design.

The Army Gun Factory is not quite so far advanced, personal legislation in Congress having materially retarded the Ordnance Department's efforts in this direction.

The large capacity of these two factories, together with the

assistance of three private corporations, will probably be able to meet all present demands.

The principal supply of material for these two gun factories comes from the Bethlehem Iron Company, which has developed its plant to a position that will enable it to deliver forgings for guns, engine shafting, and armour plate of any dimensions and weights that can be handled in the construction or armament of the ship.

The Midvale Steel Company, which has delivered a large number of forgings for the smaller calibre guns, is increasing its capacity, and will endeavour soon to deliver heavier material.

The quality of the gun material thus far produced by both these companies has been of a very high character.

The United States Congress has been sufficiently alive to any possible demand to have a careful investigation made as to location of other gun factories west of the Mississippi river.

The report of the Board instituted to make these investigations has just been issued, and recommends the location on the Pacific coast of a gun factory with a capacity such as will enable the guns of that coast to be ready at least as soon as those for the Atlantic and Gulf coasts; this factory to be situated as near as possible to the establishment which is to produce the forgings.

In laying down the requirements for the steel factory and forge, the Board recommended the methods employed at Bethlehem, and that establishment was evidently taken as a standard plant, the great capacity and enormous cost of which they recognised.

GUN CARRIAGES.

The development of the mounts for the main batteries of the navy have kept well along with the supply of naval ordnance. Excellent hydraulic service carriages (Fig. 10) have been issued for all the medium calibres, and work is well advanced upon those for the turret and battle-ships. Their designs are somewhat similar to those employed in England, differing only in various details. All carriages are so arranged that electric motors can be applied to them if found desirable. These motors will probably be supplied by the Edison Electric Company and the Thomson Houston Company.

Before entering upon a general supply, careful attention continues to be given by the army to selection from the numerous foreign types those best adapted to the land and shore defences thus far decided upon.

Among those now under trial will be found a Razzkazoff (Fig. 7), made by Easton & Anderson, another by Sir Joseph Whitworth & Co., and another by Schneider & Co., while several of the disappearing type are being manufactured in accordance with Departmental designs.

Machine Guns and Small Arms.

Little progress in the direction of the change followed by European Powers—namely, the adoption of a small calibre and a smokeless non-fouling variety of powder, has yet been made by either the army or the navy. Pending a decision upon these points (which will no doubt be reached at an early date by the recently appointed "Board on Magazine Arms"), the army continues the use of the Springfield ·45 calibre, and the navy the Lee magazine rifle of the same calibre.

The following views of the chiefs of the two Ordnance Bureaus will be interesting, not only from the point of view of their opinions on a subject at present of vastly greater importance to the European Powers than to the United States, but will serve also as an explanation of the absence of any marked progress in these particular branches, and will add more fuel, perhaps, to the spirited discussion now going on in England upon this same subject, which is one of such vital importance to the British public as well as to the army.

The chief of the Ordnance Department (army) states :—

"The lack of a sufficient quantity of a suitable smokeless powder has prevented the perfecting of all of the details of the ·30 calibre barrel, but as soon as the cartridges in process of manufacture at Frankford Arsenal are supplied, work will be diligently carried on, and it can be safely said that the barrel will be complete in all its details by the time a suitable magazine mechanism is selected. It is now eight years since the last Magazine Gun Board recommended the Lee, Chaffee-Reece, and Hotchkiss guns for experimental issue to the army. The Lee proved to be much the best

of these three, but though an excellent gun, and the original type from which the best arms in use to-day have developed, it is not considered by the army at large as equal in all respects to the service Springfield single-loader. The improvement in magazine mechanisms has been rapid since that time, and it seems peculiarly necessary, now that a change in calibre is contemplated, that our present Springfield single-loading system should be replaced, if possible, by an equally efficient magazine system. Accordingly, this office will recommend that a Board be convened to select a suitable magazine mechanism, after a full and free competition among all the best existing systems, as soon as the necessary preparations can be made. Several European nations, during the past few years, have made premature changes of calibre, or have adopted crude repeating systems that have had to be abandoned for newer and better ones, often before the armies were fully armed with them."

The chief of the Bureau of Ordnance (navy) adds:—

"Nothing has been done with regard to procuring machine guns or small arms, as the Bureau is awaiting the settlement of the question of calibre by the Ordnance Department of the army, it being extremely desirable that both branches of the service should use the same cartridge.

"It cannot be claimed that the results thus far obtained with the small calibre rifle and with smokeless powder have been found to be entirely satisfactory in any European country. The most persistently favourable results are reported from France, where the powder secrets have been well guarded; but there are reports of failures from France as well.

"It seems fairly probable that the abrupt change in European armies to the small calibre, now almost universally adopted, was made without complete justification. The ballistic results, using brown powder and perforated cartridge with the small calibre, were not satisfactory, the question of fouling entering to a disastrous extent. It then became necessary to adopt one of the nitro-explosives in order to use the small calibre bullet. This was demanded as much for its non-fouling qualities as for the smokeless feature.

"The Bureau is reliably informed that several European countries

are now to a certain extent provided with small calibre rifles, in which they cannot use the brown or black varieties of powder on account of the fouling, and for which they have not yet been able to obtain a satisfactory smokeless non-fouling variety.

"It is believed that in most cases the reduction of calibre has been too great, and that this should not go below ·32.

"It will therefore seem to be the part of wisdom to delay for a time, watching carefully the results obtained abroad, the definite adoption of any small calibre. In the meantime all the private factories in this country, as well as the Bureau, are closely observing European results, and experimenting with domestic and foreign samples where these furnish definite evidence of advantage."

From these statements it will be seen that these officials are no better satisfied with the results obtained in Europe than many of the British authorities.

The Board on Magazine Arms, before referred to, is now conducting its experiments under the following rules:—

All persons interested in magazine rifles are invited to appear in person before the Board, and submit samples under such rules as may be adopted by the Board. The arms submitted must be of calibre ·30, and must use the Frankford Arsenal experimental cartridge, except that the Chief of Ordnance may, in his discretion, submit such small arms, irrespective of calibre, for examination and test, as he may judge will prove useful to the Board.

The piece to be first fired ten rounds by the exhibitor, as a test of safety; the same firing to be also a test of rapidity by one familiar with the arm. The time to be noted in the record.

The firing to be then continued, according to the rules annexed, by an employé or person designated by the Board.

The Frankford Arsenal experimental cartridge to be used in all cases, except when pieces of a different calibre have been submitted in the manner provided by the order.

The handling of guns by their representatives at *any* time after the preliminary test for safety is *forbidden*.

Any arm which has been submitted to the Board and entered upon the record shall remain in the hands of the Board for such

time as may be necessary to make drawings explanatory of its mechanism.

If the magazine system of any gun becomes disabled or unserviceable, all further tests will be discontinued, and the proprietor informed of the fact. If the gun be altered and resubmitted to the Board, it will be treated as a new gun.

Safety test: To be fired ten rounds by the exhibitor, or with a lanyard.

Regular Tests.

1. *Rapidity with Accuracy.*

Piece to be fired from the shoulder at target 6 feet by 2 feet, range 100 feet, under following circumstances, cartridges disposed at will or in packet upon a table :—

(*a*) Time of firing and number of hits for 20 shots: magazine to be loaded before beginning the test, and then held in reserve until remainder of cartridges have been fired, using gun as single-loader; then firing those in magazine.

(*b*) Number of shots and hits firing for two minutes, using gun as single-loader; test begun with chamber empty.

(*c*) Number of shots and hits firing for two minutes, using gun as magazine arm only; test begun with magazine empty.

Any cartridge missing fire in this or other tests to be tried with a prick punch, or opened, to ascertain cause of failure.

2. *Rapidity at Will.*

Same as test 1, except that piece will be fired from the hip, without aim, at stop butt at short range; hits not considered, and time of firing for parts "*b*" and "*c*" reduced to one minute.

3. *Endurance.*

(*a*) Each gun to be fired 500 continuous rounds without cleaning, using the magazine. The state of the breech mechanism to be examined at the end of every 50 rounds.

(*b*) With magazine loaded but held in reserve, each gun to be fired as a single-loader 100 continuous rounds without cleaning; condition of breech mechanism and of the cartridges in magazine to be examined at conclusion of firing.

4. *Dust.*

With the mechanism closed, the piece to be exposed in the box prepared for that purpose to a blast of fine sand-dust for two minutes, removed, surplus sand removed by blowing thereon and wiping with the bare hand, and then fired 20 rounds under the following conditions:—

(*a*) Magazine empty when exposed. Before firing load magazine, fire balance of cartridges as a single-loader, then those in magazine.

(*b*) Magazine loaded when exposed. Remove and wipe cartridges, reload and fire as above.

5. *Defective Cartridges.*

Each gun to be fired once with each of the following defective cartridges; (1) Cross-filed on head to nearly the thickness of the metal; (2) cut at intervals round the rim; (3) with a longitudinal cut the whole length of the cartridge, from the rim up. A fresh piece of white paper, marked with the number of the gun, being laid over the breech to observe the escape of gas, if any occur.

6. *Excessive Charges.*

The piece to be fired five times as a single-loader with cartridges in which the charge of powder is so increased as to produce a pressure in the chamber about one-third greater than that caused by the Frankford Arsenal experimental cartridge.

7. *Ease of Manipulation.*

Facility of manipulation by members of the Board.

Any gun whose breech action or magazine system fails in any of the foregoing tests will not be submitted to further tests.

SUPPLEMENTARY TESTS.

To be applied only to such arms as have passed through the regular tests in a manner satisfactory to the Board.

1. *Defective Cartridges and Dust.*

(*a*) As a single-loader: To be fired with two defective cartridges, Nos. 1 and 2, and then to be dusted five minutes, the

mechanism being in the mouth of the blowpipe, and closed, but at full-cock; then to be fired 5 shots, the last two defective Nos. 1 and 2; then without cleaning to be dusted with the breech open and fired 5 shots. The piece to be freed from dust only by pounding or wiping with the bare hand.

(*b*) As a magazine arm: Same as "*a*," except that the cartridges for the subsequent firing will be placed in the magazine before dusting, and fired therefrom afterwards.

2. *Rust.*

The breech mechanism, receiver, and magazine to be cleansed of grease, and the chamber of the barrel greased and plugged, and breech action closed; the butt of the gun to be then inserted to the height of the chamber in a solution of sal-ammoniac for ten minutes, exposed for two days to the open air standing in a rack, and then fired 20 rounds, loading magazine, and holding it in reserve until remainder of cartridges have been fired, using gun as single-loader, then firing those in magazine.

3. *Explosions in Magazine.*

The liability to accidental explosion of cartridges in tubular magazines will be tested by charging the magazine, and then giving the gun a vertical jolting motion for two minutes; repeating with the magazine but half loaded.

4. *Dismounting and Assembling.*

The comparative ease and relative time required in dismounting and assembling the breech and magazine systems of the different guns will be determined.

To further determine the comparative rapidity of fire and facility of manipulation of various arms, each gun will be fired 20 shots by three men to be selected by the Board, loading from the cartridge-box, and firing from the shoulder, with aim at an "A" target 100 yards distant. The average of the three trials to be the recorded time of firing 20 rounds. The magazine to be loaded from the cartridge-box before the start, the remainder of the cartridges to be fired away first, using the gun as a single-loader, and the magazine to be emptied last.

Such additional tests or repetition of previous ones as may seem advisable will be made by the Board in its discretion.

POWDER.

Powder for both the army and navy of the United States is manufactured by Messrs. E. I. Dupont & Co., of Wilmington, Delaware. This company has acquired the rights in the United States of the Chilworth Company of England, those of the United German factories, and of the Wetteren Company in Belgium, and is therefore in a good position to supply brown powders of about the same qualities of those furnished European Governments.

Many experiments with smokeless powders have been made, and the performances of the Maxim (American) and the Wetteren (Belgium) powders have been fairly comparable with those claimed to have been obtained abroad.

Satisfactory results have been obtained with all the powders for the naval guns thus far tested.

Powder for the 35 calibre 6-inch B. L. R. maintains a muzzle velocity of 2100 feet to a 100-pound projectile with a pressure of 15 tons. The same velocity has been obtained with 35 calibre 8-inch B. L. R., and 2000 feet in the 30 calibre 10-inch gun with the same pressure. These results are considered gratifying to the naval officials, being with the same weight of projectile, and a charge of from 5 to 10 pounds less according to the calibre, from 2½ to 3 tons less pressure, and about 50 feet seconds greater muzzle velocities than have been reported as obtained in foreign services.

The Duponts have made a contract with the Navy Department for the manufacture of gun-cotton and smokeless powder, and state that they are prepared to carry out the wishes of the Government in regard to them.

PROJECTILES.

In the supply of common shell and shrapnel, until very recently the resources of the Washington Navy Yard, and of one or two companies making steel castings, were depended upon, but the Navy Department has recently made a contract with E. W. Bliss & Co., of Brooklyn, for the manufacture under the

Caley-Courtmann patents (an outgrowth of the British branch of the Simonds Company) for the manufacture of shrapnel and common shell in accordance with those patents.

While much attention has been given to it, the solution of the armour-piercing projectile problem has not yet been reached, although the army contract to the Midvale Steel Company (which will manufacture under one of the French methods), and the navy contract to the Carpenter Steel Company (which will manufacture under the Firminy-Firth patents), bid fair to procure for the country a reasonable supply of good armour-piercers.

Machine Tools.

There are several machine tool companies in the United States which now have a capacity for making most of the tools that will be required for the various steel factories and gun factories engaged in the production of war material. With the exception of a few that were purchased in order to expedite the work, the ponderous tools at Bethlehem have been designed and manufactured there, and are the most powerful and efficient of their class.

The lathes, boring-mills, planers, &c., for the two gun factories have been principally manufactured by Wm. Sellers & Co., the Pond Machine Tool Company, Bement, Miles & Co., Morgan Engineering Company, and the Niles Tools Works, and have proved especially efficient.

Torpedoes.

The United States are still without automobile torpedoes, although efforts are being made by the Hotchkiss Company to mechanically perfect that torpedo (the Howell), which so theoretically excels any other that has been designed.

The recent action of the Navy Department in domesticating the manufacture of the Whitehead torpedo may prove an incentive for the commercial success of the Howell. There is little doubt but that a decision will be reached soon, as the torpedoes of the two types will probably be put in competition, and their respective powers and usefulness determined. The Whitehead

torpedoes are to be made by E. W. Bliss & Co., while the Howell are being manufactured by the Hotchkiss Ordnance Company at Providence, R.I.

Torpedo Boats.

Practically no progress has been made in this direction, as the country possesses but *one* torpedo boat, the *Cushing* (Fig. 11), built by the Hereshoff Manufacturing Company, a type only of what a native builder can produce.

No great progress can be made in this line of warfare until a sufficiently large appropriation is made to encourage some company to collect all the best elements of the various types, and incorporate them in a large number of boats laid down at the same time. If these sparrows are to be employed, a large number of them are necessary, and very little progress can be expected if boats are built singly and at long intervals.

Submarine Boats.

In the direction of submarine boat construction nothing has been done save an endeavour to secure proposals that would contain a guarantee of performance on the part of the boats of the functions required by the Department, which considered the following features essential to the usefulness of a submarine boat:—

Great safety, facility and certainty of action when "submerged," fair speed when "covered," good speed when running on the "surface," a fair endurance of power and stores, great ease of manœuvring under all conditions, sufficient stability, great structural strength, and fair power of offence.

The Holland and Tuck designs have been pushed forward by their respective advocates, but none of the designs have been deemed of sufficient commercial interest to be practically undertaken.

In 1887 and in 1888 the Navy Department advertised for proposals and received bids from the Cramp Shipbuilding Company and two other firms; and, although the Department was impressed with the Holland-Cramp design, the absence of any guarantees prevented their acceptance.

Although the United States may appear to be somewhat in the rear of European nations in this branch of warfare, none of the European boats seem to have been, as yet, eminently successful.

RAMS.

The United States has considered ramming a sufficiently important factor in naval tactics to authorise the construction of a 2000-ton vessel, intended solely for ramming. It is being constructed after the designs of Rear-Admiral Daniel Ammen of the United States Navy, and is to have a speed of 17 knots. She will, however, possess the disadvantage of a *fixed* ram, unless the experiments with the Ericsson submarine gun should be of such a definite nature as to cause the substitution of the *detachable* ram.

The ram has given such practical proof of its power both in intent and accident, and is so easily provided for in the design and construction of the ship itself, that such a weapon should be looked upon with much favour by naval constructors, as well as by artillerists and naval commanders. With minute cellular hull, coal storage, india-rubber, woodite, cellulous, and other devices to lessen the effect of rupture below the water-line, the power of the ram must be increased over what has thus far been obtained by the form of the attached ram itself, and it is claimed that this augmented power can be obtained by the device herein described as the Ericsson detachable ram.

Sir Nathaniel Barnaby says: "I think the time is coming, if it has not already come, when there will be a demand not only for the recognition of the equal claims of all fighting ships to keep afloat against the attack of the guns which they will have to face, but also the equal protection of their own crews between decks against the overwhelming effects of the bursting of high explosives there."

In direct connection with what Mr. White has said regarding the probability that ships of war could be put out of action without destroying side armour, I have the pleasure to present to the Institution the latest developments that have taken place in the United States in submarine design, and the action that the United States Navy Department has taken in regard to it.

In analysing the powers of weapons Captain Grenfell says: "If the torpedo and gun are at best on a par as regards destructive effect, the ram is certainly superior to either of them. But as the torpedo is much more limited in range than the gun, so the ram is a long way behind both, its effect being confined to actual contact between the ships.

"What may be termed the chances of inaccuracy in its use are also enormous. Students of Admiral Colomb's writings will know what a hair's-breadth separates, in a ramming attack, the case of ramming your adversary from that of being yourself rammed. At the worst a failure with gun or torpedo is but a lost shot, but in ramming, if you fail, you may bring immediate destruction on yourself. It is no doubt this terrible uncertainty which has thrown into the background the proposals to use the ram as the chief mode of attack which were so numerous some years ago."

It is the aim of the Ericsson detachable ram or the projectile which is to be fired from the submarine gun to meet these objections, and to reduce to a minimum the dangers attending ramming with a fixed ram.

To remove the impression that exists in the minds of many who believe that a comparison must be drawn between the velocities and ranges of submarine guns with those obtained by the automobile torpedoes, allow me to explain that it is not intended to secure such ranges by this system, but rather to substitute for the *attached* ram, to the power of which so much importance is given, a *detachable* one, by which the dangers of the ram and the risk to the rammer can be avoided or reduced, and a ram obtained which will practically be several hundred feet in length.

The construction and mechanical arrangement of the gun and projectiles are so simple that only a limited description will be necessary to supplement the annexed drawings (Figs. 12 and 13). The firing of explosive projectiles from guns arranged under water has been attended with much danger, owing to the liability of the projectile to be exploded before leaving the gun by the firing-pin striking the valves that were used to exclude the water. By the substitution of a suitable packing these valves are now done away with, and by means of compressed air the firing position of the projectile (Fig. 12) is controlled. The gun

(Fig. 12) is breech-loading, with powder discharge. Any system of breech mechanism may be employed. Experiments with the later mechanisms have been very successful, and all the difficulties have been overcome that caused the failure of an *earlier* type of this weapon at Milford Haven in the year 1885.

The United States Congress, by an Act approved June 30, 1890, appropriated $30,000 for the purpose of enabling the Secretary of the Navy "To manufacture and experimentally test, under rules and conditions to be prescribed by him, a submarine gun and projectile for the same $30,000: Provided, that no part of this money shall be expended until the owners of the patents to be tested under this provision shall agree by contract to give the Government the option, within a specified time, to contract, at such price as shall be satisfactory to the Secretary of the Navy, for the exclusive right on the part of the Government to manufacture by contract, or otherwise, such submarine guns and projectiles without the payment of any royalty on the same: Provided, that such submarine gun and projectiles shall prove satisfactory, on due test, and be approved by the Secretary of the Navy."

In pursuance of this Act, the Navy Department, under date of September 19, 1890, entered into a contract with the Ericsson Coast Defence Company for one submarine gun and six steel projectiles, the gun and projectiles to be fixed and secured in position on board the steam vessel known as the *Destroyer*.

The Secretary states, "It is proposed to make a thorough test of this system of submarine artillery, which possesses undeniable advantages, if applied to special types of vessels, such as the ram designed for work at close quarters. The experiments will be conducted at the torpedo station at Newport."

In order to obtain the accuracy of aim, the instantaneousness of discharge, and the rapidity of flight, which Captain Grenfell claims is found in a much superior degree in the flying air torpedo than in its submarine brother, an aerial subaquatic torpedo (Fig. 13) has been designed for the Ericsson Coast Defence Company, which possesses, in addition to its aerial range, an automatic subaqueous range of sufficient scope to have a very large additional chance of getting in its destructive work. Several of these are in course of manufacture for the two Departments.

The effective zone of submerged high explosives being limited, their destructiveness as used in aerial torpedoes has hitherto depended solely on the accuracy of range very hard to obtain, except at very close quarters, as they must be dropped very close to the vessel's side. The object of the Ericsson Company's aerial subaquatic projectile is to secure such an automatic steering of the projectile in a vertical plane, after it enters the water, that whether this takes place at a distance of 100 or 700 feet from the vessel's side the projectile will hit the submerged hull at a predetermined depth. The pilot shell is detachable, and only intended to be used against vessels carrying torpedo-nets. Its object is to destroy the net, opening a breach of sufficient size to enable the projectile to pass through.

In expressing my appreciation of the opportunities that have been given me for such close association with almost every detail—legislative, military, and manufacturing—of the work of establishing on United States soil the industries for the supply of modern heavy ordnance and armour that have again made us independent of our British cousins, I have to thank many of you for much information and courtesy.

I desire further in this connection to pay special tribute to the great engineering work that has been accomplished by two already famous engineers—Manasseh Gledhill of Manchester, and John Fritz of Bethlehem; to the genius, ability, and perseverance of each, respectively, is largely due the typical character of the great ordnance works of Sir Joseph Whitworth & Co., Limited, and the Bethlehem Iron Company.

If undue prominence seems to have been given to the work with which I am directly associated, it must be credited to a most natural pride in what the Bethlehem Company has accomplished.

It has not only laid the corner-stone, but is rapidly and faithfully raising the structure, so vital to a defence of the wealth and population of the United States.

DISCUSSION.

The PRESIDENT said that the Institute was much indebted to Mr. Jaques for the most interesting and comprehensive paper that he had prepared, giving an account of the present condition of the resources for the manufacture of war material in the United States. What the full portent was of the remarkable progress which had of late been made in this direction in America it was difficult to say. At any rate, it was evident that even in these matters we now had formidable competitors in our friends in the United States. The subject had been dealt with very completely, and he did not know that there was any point upon which he could at that period of the meeting invite discussion.

M. JULES GARNIER (Paris) stated that he agreed entirely that nickel in small quantity in steel armour plates prevented cracks, and it also increased the penetration of the shot. As for the matter of hardness, although M. Barba had said it could be increased when nickel attained 20 per cent. in steel, M. Garnier maintained that it was only so in appearance. Indeed, the hardness observed was derived from other substances contained in the alloy. The affinity between nickel and iron was so great that the alloys of those metals were quite complete. Pure nickel being naturally very soft, its molecules seemed to tie together the molecules of iron so as to prevent the cracks. As for the penetration of shot, it could be prevented only by the hardness of the alloy; but nickel was not hardened by carbon, and it seemed that even when it was alloyed with steel it substituted itself for the carbon of the steel, which was no longer combined, but isolated, so that the nickel-steel itself was no longer hard, and was easily penetrated by a shot. When the proportion of nickel was increased in the steel, the percentage of carbon was generally diminished, and the alloy being no more divided by isolated molecules of carbon, looked harder. M. Jaques said that with the probable employment of high explosives, penetration was a serious matter, because they could load the explosive chambers of shells with

high explosives. M. Garnier agreed that this would be the case *unless they hardened* the nickel-steel with other substances, such as carbon. His friends, Les Acieries de la Marine de St. Chamond, in France, did precisely so resolve the question, and obtained the hardness of nickel-steel by other substances, such as carbon alone. They quite succeeded in this, as the photographs of such armour plate trials, which M. Garnier exhibited, fully showed. The armour plate manufactured from "Metal special de St. Chamond" was fired at by six shots weighing 41kg., with a speed of 675m.; the penetration averaged 0m.260, no cracks were observed, and the distance between the shot-holes was 0m.580.

M. Garnier added that from the year 1875 he had studied the alloys of nickel and iron with modern metallurgical apparatus. He had observed how much even a small proportion of sulphur rendered nickel and its alloys brittle, and his researches showed him that a certain kind of flux in a basic furnace allowed of taking off the least quantities of sulphur from nickel or from its alloys with iron.

M. Garnier placed on the table some specimens of an alloy of iron and nickel, which contained at first about 3 per cent. of sulphur, but which now contained only 0·03 per cent. of sulphur. That product, prepared on a large scale at the steel works of St. Chamond (France), was quite good enough to give any kind of nickel-steel.

CORRESPONDENCE.

Mr. W. H. White, C.B., F.R.S. (Director of Naval Construction), has submitted, by request, the following notes on Mr. Jaques's paper:—

As a record of the rapid development in the manufacture of war material this paper has great interest.

No doubt the careful study of what had been done in this and other European countries, by competent officers despatched for the purpose, was of the greatest assistance in the development of similar manufactures in the United States. But even allowing for this circumstance, and for the undoubted benefits which resulted from the experience gained elsewhere, what has

been done in a comparatively short time in the production of ships, armour, and armaments, is very remarkable.

In relation to ships it is unnecessary to add anything to the remarks which I made at the Institution of Naval Architects in March last.

As regards the materials used for ship, engine, and boiler construction, the codes of tests which are reproduced by Mr. Jaques are obviously based, to a great extent, upon the similar regulations which have been in force here and elsewhere. There are certain variations in details and in the lower limits of tensile strength, but in the main the regulations are not more stringent, nor does the inspection seem to be more severe, than the corresponding conditions in this country.

Mr. Jaques dwells at great length on the armour plate question, and he gives some very interesting information as to recent tests made in America, particularly on the so-called Harvey armour plate, and on the plate made by the Bethlehem Company.

The elaborate statement of his own views on the question of steel, nickel-steel, or compound armour, will also be read with interest in view of the great attention which Mr. Jaques has given to the subject; but it scarcely appears that this section strictly belongs to the subject which the title of the paper indicates.

More information as to the actual development of armour plate making in the United States is to be found in the last report of the Secretary of the Navy, from which it may be gathered that considerable difficulty has arisen, and still exists, in obtaining from home manufacturers the large weights of armour required for ships in course of construction.

Mr. Jaques refers to the action of the British Admiralty in the matter, and makes several direct allusions to the part which I have taken in connection with recent armour plate trials in this country. I do not propose to say much on the personal question, but I may remark that from the very outset it has been my endeavour to assist in securing for Her Majesty's ships the best description of armour obtainable at any time.

Further, it has been my conviction, and still remains so, that from British manufacturers there can be obtained material certainly equal to that which can be procured from any other makers in the world.

The experiments on board the *Nettle* to which Mr. Jaques alludes have been made under the orders of the Admiralty for the purpose of ascertaining how the best steel armour now procurable compares with the latest examples of compound armour. Mr. Jaques speaks of these as private trials, and appears to think that the Admiralty are under some obligation to communicate to the public of all countries the results of these trials. This opinion Mr. Jaques is of course free to hold, and I can quite understand that it would be advantageous to him and to many others to have in their possession information which the Admiralty has obtained by long-continued experiments carried on at considerable cost.

The policy of the Admiralty, however, has not been such as Mr. Jaques would infer. On the contrary, the Admiralty has desired to encourage British manufacturers in undertaking armour plate making, and has given to each manufacturer the fullest information in relation to the tests of his armour plates. This course has had the result of enabling individual makers to effect considerable improvements in successive plates, and the main results of this long series of trials have been to show that steel armour plates have been very greatly improved in their quality during the last ten or twelve years; that they can now take rank with compound armour plates of the best quality obtainable; and further, that steel armour plates are actually being made in this country in no sense inferior to steel armour plates made elsewhere.

Mr. Jaques makes one statement which must be strongly objected to, viz., where he says, "that with European governments, and Great Britain especially, the pride of protecting their industries keeps up the fight for the defence of compound armour."

Any one who will take the trouble to read the discussion which recently took place at the Institution of Naval Architects on a paper contributed by M. Barba of the Creusot Works, will see that there is no justification whatever for Mr. Jaques' statement as far as the British Admiralty is concerned. And further, that the great English manufacturers who have done most to develop compound armour have also shown their capability in the manufacture of steel armour of the highest quality, although their conviction is that on the whole compound

armour is still to be preferred. Mr. Wilson's remarks on this head are especially noteworthy.

The Admiralty has sufficiently indicated its attitude on this matter in placing recent orders for the armour of two sister-ships, the defence of one of the ships consisting of all-steel armour, and the other of compound armour.

The simple truth is, that this competition between different modes of making armour has run through many chapters, and no final relative result has yet been obtained.

It may be frankly admitted that steel has undoubtedly gained relatively to compound armour in recent years; but, in view of the latest experiments, and of the possibilities of further progress, it would be idle to assume that any final result has yet been reached.

In the discussion at the Institution of Naval Architects, to which allusion has been made above, I gave a sufficiently complete account of the Admiralty action in relation to nickel-steel during the last two years; and it is scarcely necessary for me here to do more than say that, from the very first publication of Mr. Riley's results, the Admiralty and its officers have done all in their power to determine experimentally what are the advantages of nickel-steel as compared with other kinds of armour. At the present time the thin armour (3 and 4 inch) for several ships is being manufactured of nickel-steel; while experiments are proceeding on 10½-inch nickel-steel armour plates produced by three of the leading English manufacturers.

Dr. Francis Elgar (Director of H.M. Dockyards, Admiralty), remarks:—The portion of this paper that has most interest for myself is that which relates to the progress made during the last few years in the United States in developing—I may say creating—the means of production of modern ships of war. No one who is not acquainted with the details of war-shipbuilding would imagine how difficult it is to commence at short notice the construction of modern ships of war, or even to bring up to date, in establishments that have been manufacturing on old lines, the appliances, the *personnel*, and the administration which are necessary for the work. I have twice visited some of the principal navy yards and private shipbuilding works in America during the last three years, and have been much struck by the great progress made

during that time, and still more by the enormous changes since a previous visit made six years before. Nine years ago an English visitor to American ship-yards and marine engine works saw much that was interesting and—to him—novel in the construction of vessels for trading upon the coasts and the great lakes, and especially in some of those wonderful specimens of marine architecture built for carrying passengers upon the rivers, but he saw little beyond which impressed him either by its merit or its novelty. The war-ships of the navy belonged to a bygone age. The ironclad monitors that had been produced by the energy and genius called into play during the Civil War had become obsolete, and the only questions concerning them were whether they and others that had long remained incomplete upon the stocks could be modified so as to come up to the modern standard of fighting power.

This state of things is now of course altered. Three years ago the development of all classes of naval war material was increasing enormously. Two ironclad coast-defence ships, cruisers of various types, naval guns, and mechanical appliances for working them on board ship, and the trial of new weapons, such as the dynamite gun, were being rapidly pushed forward. It was noticeable, however, that there was little experience to guide many of those who were carrying out the details of the work, and that some of the tools and appliances were not the most advanced of their kind. A very great improvement was apparent, however, last autumn. Machine tools had everywhere been improved, and brought up to date in number and quality. Those in charge of work, and the workmen themselves, had gained experience, and many improvements had been made in the arrangements and fittings of ships, boilers, and machinery, which are the pure outcome of native study and practice.

America has had a good opportunity for entering upon the business of building up such a fleet of modern war-ships as she requires, and she appears to have used the opportunity in a careful and practical way. Starting from the position that in Europe experiments of all kinds have long been, and are continually being, made in war-shipbuilding, and that these are always being tried and criticised, the Government collected all the information it could obtain from abroad upon the subject, and investigated it

from an outside and impartial point of view. Officers of the navy, and of the Construction and Engineering departments, visited the ship-yards and marine engineering works of this country and the Continent, and not only collected valuable information, which was embodied in reports to their Government —many of which have been published, and are made available for the instruction and use of all of us—but also educated their minds and judgments by coming into contact with many different ideas and systems, and discussing and analysing these as they went along. The American Government has also been selecting some of the best students out of the United States Naval Academy, and sending them to take the course of technical instruction at the Royal Naval College, the University of Glasgow, or some of the colleges of instruction on the Continent. I have had a little to do with some of these students, and have formed a high opinion of the ability, energy, and good qualities of those selected by the United States Government to be responsible for the future of shipbuilding in America. With such material to draw upon for the creation of naval architects and marine engineers, and such resource and intelligence, and capacity for improvement, as is to be seen in the various works in America, there can be no doubt as to what the future of shipbuilding will be in that country, when tariff arrangements are made that will not handicap an American shipbuilder or engineer in competing with foreign builders.

I do not believe that, if the tariff difficulties were removed, there would be reason to suppose that extra cost of labour, or of anything else, would prevent America from competing with this country in the production of ships, marine engines, guns, or other war material. Whatever there might be in our favour in that way, there are other advantages in America which tell upon the other side. Mr. J. Russell Lowell once said in this country, when speaking of the difference between American and other workmen, that "the American workman mixes more brains with his fingers." I think there may be something in this. There are not better workmen, or better foremen in charge of work, in the United States than many who could be found in this country, but I would say, as the result of observation of workmen in American ship-yards, engine works, &c., and of con-

versations with foremen and managers, that the average quality is better. There is not such a long tail of indifferent mechanics as is often to be found amongst ourselves. The foremen and sub-managers of departments are often above the average of ours in intelligence and resource, and in possessing that faculty which enables a man to see how to employ labour in exceptional cases to the greatest advantage, and how to continually improve the efficiency and economy of labour.

It has been most interesting to see what has been going on in the United States in connection with the subject of this paper during the last three years. The Bethlehem Iron Works is a well-known and wonderful instance of American enterprise and progress. This and other large manufacturing firms have incurred great trouble and expense in enlarging their works and adapting their plant and staff to fulfil the Government requirements for war material, however extensive these may become.

My own present work has led me to regard the recent rapid developments in the production of war material in America with special interest. Five and a half years ago I was placed in charge of that department at the Admiralty which is responsible to the Controller of the Navy for the work done in Her Majesty's dockyards. Since then we have built many ships of all classes, and have started the manufacture of marine engines. We have tried to make improvements where we could that would increase economy, despatch, and efficiency of work. We have made progress in this country in many directions, both in the royal dockyards and among private shipbuilders. I have never seen anything, however, equal to the progress in America during the last few years, and the rapidity with which the means of production of shipbuilding material have been increased, and naval constructors and engineers have acquired the power to supply the Government with all they may want of the most modern naval ships and weapons. What I have seen in this and other countries has caused me to believe that America may take the lead later on in the improvement of warships if she make it an object to do so. There is, of course, in America a freedom from prejudice—or of interest in old processes and systems that are difficult to disturb, or even to regard impartially, in countries where they have grown into custom;—besides the ability and

knowledge which ensures the best points being selected out of all systems, and the worst rejected, and those that are kept being used as a basis upon which to build improvement and future progress.

The tests for ship plates, boiler plates, protective plates, steel castings, shafting, &c., which are quoted in the paper from the United States specifications, differ somewhat from those employed in this country. Our tests are mechanical, and if the materials comply with the mechanical tests, and do not fail under manipulation by the workmen, we do not trouble about chemical tests. More elongation is required in America of the test-pieces before rupture—25 per cent. for ship plates, as against 20 per cent. by our Admiralty and 16 per cent. for Lloyds—and no maximum limit is fixed for tensile strength. The Admiralty have a maximum limit for tensile strength of 30 tons per square inch, and Lloyds 32 tons. Some of the cold-bending tests and others are also more severe than ours.

The relative qualities of the various kinds of armour will doubtless soon be thoroughly tested in America. Everything necessary for a complete solution of the problem of the most perfect armour for the sides of ships or for decks can now be produced there; and there seems no longer any necessity for Mr. Jaques to look outside his own country for many of the trials he requires. The various questions connected with the chemical constituents of the materials, or in the processes of manufacture, can all be fully dealt with in America upon neutral ground. Much of the argumentative portion of the paper which relates to armour plating will doubtless soon be settled by trial.

The President said that the business of the meeting was now completed, except that he would ask the members to pass a resolution which, although it was a matter of course, was at the same time a pleasant duty, viz., to give the best thanks of the Institute to the President, Council, and Secretary of the Institution of Civil Engineers for the use of their rooms, and for the facilities otherwise afforded to the present meeting.

This motion was duly seconded, and adopted by acclamation.

Mr. G. J. Snelus, F.R.S., said it was his pleasing duty to propose, "That the cordial thanks of the members of the Iron and Steel Institute be, and are hereby, tendered to Sir Frederick A. Abel, K.C.B., F.R.S., President, for his conduct in the chair." He was quite sure that they could not have had a better successor than Sir Frederick to the worthy President who had just retired. As they all knew, Sir Frederick Abel was a scientist of the very highest attainments, and they owed a great deal to the investigations which he had made as to explosives, and also in connection with their own special subject of iron and steel. It was a great task for a gentleman in his position, who had such multifarious things to attend to, to bestow so much time in the service of the Institute, and he was sure the members would desire to accord him a hearty vote of thanks.

Mr. P. C. Gilchrist seconded the motion, which was unanimously adopted.

The President said he was greatly indebted to the members for their kind expression of thanks.

The meeting was then concluded.

APPENDIX.

THE IRON AND STEEL INSTITUTE.

STATEMENT OF ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1890.

RECEIPTS.

To Investments, December 31, 1889		£7003 14 11
,, Entrance Fees	£357 0 0	
,, Subscriptions	2971 10 0	
,, Journals sold	202 15 0	
,, Interest	274 11 3	
		3805 16 3
,, Bessemer Medal Fund—		
Income, 1890	£15 12 0	
Balance from previous years	10 15 6	
		26 7 6
,, Balance due to Treasurer		1378 3 1
		£12,214 1 9

EXPENDITURE.

By Balance due to Treasurer, December 31, 1889		£360 0 9
,, Salaries of Secretary and Clerks	£720 0 0	
,, Office Rent, Cleaning, &c.	331 18 9	
,, Purchases for Library and Office Furniture	14 15 6	
,, Editing and Translating	165 18 0	
,, Expenses in connection with Annual Meeting in London, May 1890	39 12 4	
,, Expenses in connection with Meeting in America, October 1890	592 14 4	
,, Presentations in recognition of special attention shown in America by various persons and Corporations	405 10 3	
,, Journal Publishing Expenses	961 6 10	
,, Printing, Advertising, and Stationery	357 3 2	
,, Insurance	1 0 0	
,, Postages, Receipts, &c., per Treasurer and Secretary	99 8 9	
,, Sundry Payments	70 15 6	
,, Bessemer Medal	15 5 0	
,, Special Bessemer Medal and Diploma Expenses	35 3 1	
,, Inland Revenue—Corporation Duty (3 years)	31 0 7	
		3841 12 1
,, Investments—		
In £1170 North-Eastern-Darlington 5½ per cent. Stock, at a cost of	£1738 8 9	
In £1681 North-Eastern 1876 4 per cent. Preference Stock, at a cost of	1998 19 7	
In £630 North-Eastern Darlington A 5 per cent. Stock, at a cost of	1008 14 0	
In £1546* Scinde, Punjaub, and Delhi 5 per cent. Stock, at a cost of	1999 0 7	
In £750 Great Indian Peninsula Railway 5 per cent. Stock, at a cost of	1267 6 0	
		8012 8 11
		£12,214 1 9

DAVID DALE, *Hon. Treasurer.*

DARLINGTON, *May* 1891.

* This has since been compulsorily converted into an Annuity up till 1958, with a Sinking Fund to replace the amount of Stock, £1546.

OBITUARY.

JOSEPH WHITLEY, of the Railway Works, Leeds, was a native of Wakefield, and was born in 1816, his father having been one of the chief hands at Hayden's Engineering Works, Wakefield, where the son also began his career. In 1832 the latter removed to Leeds, and was employed at the engineering works of Messrs. Fenton, Murray, & Jackson. He began business on his own account in 1844, since which time he has been at the head of the firm of Joseph Whitley & Co., later Whitley Partners. He has been described as "the best bronze-founder in the world," having in recent years produced bronze of remarkably high tensile strength, density, and homogeneity. Mr. Whitley's exhibits at the Inventions Exhibition, illustrating the manufacture of cylindrical forms in bronze, was a new feature of importance to the engineering world, consisting in the spinning of liquid metals under the influence of centrifugal force, thereby attaining at once perfect homogeneity, greater density, and superior tensile strength. Mr. Whitley's exhibits further included a spun roller, consisting of several layers of different classes of iron, the outer or inner layer of which may be hard or soft, yet of one solid mass, as the case may require. The results of these applications are becoming more appreciated in mechanical engineering, especially where great tensile strength is required.

As an inventor, Mr. Whitley has been most prolific and varied, having taken out from first to last about fifty patents, between 1858 and 1887. His patents have covered improvements in iron, the manufacture of railway wheels and tyres, the casting of metals, and the moulds required for that purpose, the manufacture of weldless corrugated tubes, of steel and other boilers, of metallic shells and torpedoes, apparatus for the development of electricity, and improvements in the construction of ships, composite metallic plates, rockets, valves, railways, and machinery for the manufacture of acids. He had also worked long

and successfully in the wide field of the production of alloys, a field that has within recent years assumed greatly increased importance. Ordnance was another of Mr. Whitley's hobbies, and he produced at his works in Leeds several experimental bronze guns that attracted some attention. While essentially a mechanical engineer and metallurgist, Mr. Whitley did not strictly confine his ideas and activities to the domains that are occupied by these professions, large and varied though they be, but he took an occasional excursion into other fields of research, and in them found original ideas for the ornamentation of textile and other fabrics, the treatment of sewer-gas, and other equally diverse subjects, which were patented. Probably, indeed, the versatility of his mind was not always so favourable to the business success of Mr. Whitley as might have been expected, since he had no sooner found the solution of one problem than he set himself to formulate and solve another. But whether for himself or for others, Mr. Whitley did good work in his day, and was in some important directions a pioneer who is entitled to grateful remembrance. Mr. Whitley's eldest son, who was also for several years a member of the Iron and Steel Institute, is Mr. John R. Whitley, the originator and director of the several exhibitions held during recent years at Earl's Court.

√RICHARD SMITH, who died at his residence in London on the 7th of August 1891, was one of the original staff of the Royal School of Mines, on its formation in 1851. He was associated with the late Sir Henry de la Beche, Dr. Percy (Past-President of the Iron and Steel Institute), and others in laying the foundations of the extended career of usefulness by which that establishment has been distinguished during the last forty years. While the Museum of Economic Geology, which preceded the Royal School of Mines, was located in Craig's Court, Charing Cross, Mr. Smith became junior assistant to the late Mr. R. Phillips, F.R.S., as chemist, and on the transfer of the Museum to Jermyn Street, where it has since been carried on, Mr. Smith was appointed Dr. Percy's assistant in the metallurgical laboratory. In that capacity Mr. Smith has been a most successful demonstrator and teacher, although always discharging his duties in such a quiet and unobtrusive manner that he never sought, and perhaps, except from those who came into intimate contact with him, never received, the credit to which their faithful and capable performance entitled them. Many of the students who have passed through his hands are now filling important positions in mining, metallurgical, and engineering

spheres, and by these, at least, he is likely to be gratefully and affectionately remembered.

The late Mr. Richard Smith undertook, in the laboratory of the Royal School of Mines and elsewhere, many original investigations into abstruse or imperfectly known metallurgical problems. The results of not a few of these have been communicated to the world through the volumes of Dr. Percy's "Metallurgy," and have been duly acknowledged by that writer. But although he did much valuable work for and through others, Mr. Smith was of too retiring a disposition to seek publicity for himself, and his independent communications to the literature of the subject of metallurgy have been comparatively few. As a notable example of this fact, it may be mentioned that he has never made any communication to the Iron and Steel Institute, which he joined, on the nomination of his superior, Dr. Percy, in 1887. He acted as Laboratory Demonstrator at the Royal School of Mines until the commencement of the present year. Paralysis was the immediate cause of his death.

Lord Edward Cavendish, third and younger surviving son of William, seventh Duke of Devonshire, died at Devonshire House, Piccadilly, on Monday the 18th day of May last, from pneumonia following an attack of influenza. Lord Edward was the third member of his illustrious house who had formed an intimate association with the affairs of the Iron and Steel Institute, his father having been the first President of the Institute (1869–70), and his next oldest brother, Lord Frederick Cavendish, having been, for a number of years, a member of Council, while he himself had been a Councillor of the Institute since 1886.

Lord Edward was born in 1838, his mother having been the late Lady Blanche Georgiana Howard, fourth daughter of the sixth Earl of Carlisle. He was educated at Trinity College, Cambridge, and entered the Rifle Brigade in 1860, retiring in 1865. In that year he was elected M.P. for East Sussex as a Liberal, but was defeated in 1868. In 1873–74 he was private secretary to Lord Spencer, the then Lord-Lieutenant of Ireland, and in 1874, with Sir J. Kay-Shuttleworth, he unsuccessfully contested North-East Lancashire against Mr. J. M. Holt and Mr. J. P. Starkie. He was a magistrate for Sussex and Lancashire, and a magistrate and D.L. for Derbyshire, Lieutenant-Colonel Commandant of the 3rd Battalion Sherwood Foresters (Derbyshire Regiment) from 1881 till 1888, and he had been

Lieutenant-Colonel of the 1st Volunteer Battalion of the Royal Lancashire Regiment from 1888.

The late Lord Edward was closely connected with Lancashire industries, being a director of the Barrow Hæmatite Steel Company and of the Furness Railway Company. He was also on the board of the Alliance Assurance Company.

He was elected member for North Derbyshire in 1885, in succession to his uncle, Lord George Henry Cavendish, and was returned for the western division of the county in November of that year, defeating Mr. F. C. Arkwright. He was returned for the same division without opposition at the General Election of the following year as a Unionist. Since that time he had acted as Whip for the Unionist party.

Lord Edward married, in 1865, the Hon. Emma Elizabeth Lascelles, who was the fourth daughter of the late Right Hon. William S. Lascelles, M.P., and Lady Caroline Lascelles, and was formerly a Maid of Honour to Her Majesty and a Lady of the Bedchamber to the Princess Christian. He had issue three sons, the eldest of whom, Victor Christian William, was born in 1868.

The Queen, on hearing the news of Lord Edward's death, sent an immediate message of condolence to the bereaved family, as did also the Prince and Princess of Wales. The sad intelligence was also received with general regret throughout Derbyshire, while at Barrow and in the district the flags on the ships and the public buildings were hoisted half-mast high. Hundreds of letters and telegrams expressing sympathy and regret were received at Devonshire House from all parts of the country.

GRANVILLE GEORGE LEVESON-GOWER, second Earl Granville, who died at the residence of his nephew in South Audley Street, London, on the last day of March 1891, was born in 1815, the year in which his father was raised to the peerage. The first Lord Granville, a younger son of the Marquis of Stafford, had been a diplomatist of considerable distinction. In 1804 he had gone to St. Petersburg on a similar mission to that which subsequently was to be confided to his son, and had attended the coronation of Alexander as our Ambassador Extraordinary. In 1836 he was Minister at Paris, and his son, who had been educated at Eton and Oxford, was attached for a time to the legation. But the actual apprenticeship that the young man served to regular diplomacy was a short one; and in 1837 he was returned to Parliament as member for Morpeth. Three years afterwards he was

appointed to the office of Under-Secretary for Foreign Affairs; but in a short time afterwards the Melbourne Ministry was broken up. Having lost his seat for Morpeth, in 1841, he came back to the House of Commons as representative for Lichfield, and made himself somewhat conspicuous for the vigour and ability with which he advocated the cause of the Anti-Corn Law League and the principles of Free Trade. Five years later, on the death of his father, he took leave of the Commons. At a later date he was made Master of the Buckhounds, a post that seemed admirably suited to one who, notwithstanding his spirited speeches on Free Trade, had been chiefly thought of as a graceful courtier and a polished man of the world. In 1848, Lord John Russell transformed the Master of the Buckhounds into his President of the Board of Trade, which caused Mr. Bright to speak the mind of the manufacturing interest with more than his accustomed bluntness in making a far-fetched charge of Nepotism against the Premier, but Lord Granville made a good impression at the Board of Trade, although yet a young man. As a clear-headed and energetic man of business he gave proof of those versatile abilities which marked him out a year or two later as Vice-President of the Commission for the International Exhibition. In that capacity his geniality and his business powers won him golden opinions from all conditions of men. His closer relations with Her Majesty and the Prince Consort confirmed, if they did not originate, the warm personal regard which those illustrious personages always expressed for him; while foreign exhibitors, and especially our French friends, were never weary of praising the unfailing courtesy and the winning polish of manner they were so well fitted to appreciate. Perhaps few things did more to foster the *entente cordiale* which was to exercise so important an influence in European politics than the manner in which Lord Granville represented his country at the *fêtes* offered to the English Commissioners by the Paris Municipality in honour of the Exhibition; and in particular his speech at the banquet of the Hôtel de Ville was much praised as a triumph of oratory by an audience which he flattered by his ready command of their language.

In 1859, after he had had a short preliminary experience of the Foreign Office, the Queen sent for Lord Granville on the fall of Lord Palmerston. Lord John Russell, however, declined to serve under Lord Granville, and this fact solved the difficulty. Meantime his Lordship became Chairman of the Royal Commission of the Exhibition of 1862, and three years later he was appointed Lord Warden of the

Cinque Ports. In 1870, on the death of Lord Clarendon, he became Foreign Secretary, and he held that office until Mr. Gladstone dissolved in 1874. He again filled that important post from 1880 to 1885, and subsequently, in two different administrations, he held the office of Colonial Secretary.

For nearly half a century Lord Granville led his party in the House of Lords with imperturbable temper, unfailing tact, and ever-ready wit. His geniality and conciliatory disposition helped to tide over the conflict between the two Houses which seemed to be rendered inevitable by the party strife over the Reform and Redistribution Bills. He retained his position as leader in the Lords to the close of his life. When Mr. Gladstone returned to office as a Home Ruler, he was followed by Lord Granville, but he did not replace Lord Granville in the Foreign Office, which he assigned to Lord Rosebery, a rapidly rising statesman of a younger generation. Lord Granville took, for the second time, the Colonial Office, and this was his last office as minister. In spite of much adverse criticism, and not a little unjust blame, Lord Granville's spirit never flagged, and his temper rarely showed signs of friction. But he ceased more and more to take a conspicuous part in politics for some time previous to his death.

Besides his political offices and his connection with the Exhibitions of 1851 and 1862, Lord Granville had gone in 1856 to St. Petersburg as Ambassador Extraordinary at the coronation of the Czar; and in the same year he had been elected to the Chancellorship of London University. He was made a K.G. in 1857.

Lord Granville was for many years intimately connected with the iron trade as an ironmaster and colliery-owner, having carried on the Shelton Bar Iron and other works in Staffordshire and Shropshire. In this capacity he naturally took a great interest in the proceedings of the Iron and Steel Institute, and frequently attended the meetings in London. The last meeting he attended was that held in May of 1890, when he gracefully proposed a vote of thanks to Sir James Kitson, the then President. He was one of the original members of the Institute.

Lord Granville was twice married—in 1840 to Maria Louisa, only child and heiress of Emeric Joseph, Duc de Dalberg, and widow of Sir Ferdinand Acton, whom he lost in 1860; and again, five years afterwards, to the youngest daughter of Mr. Campbell of Islay, who survives him. He is succeeded by his son Granville George, Lord Leveson, who was born in 1872.

BENJAMIN WALKER, who died on the 14th April 1891, at Moor Allerton Hall, Leeds, was born at Armley, near that town, on the 20th April 1821. At the age of fourteen he was apprenticed to an engineering firm in Leeds—Messrs Newton & Taylor—and at the age of twenty he became foreman of a large shop. He received a large part of his education at a night-school in Armley, near Leeds, walking direct from the workshop in Water Lane to the school. At the age of twenty-one, when his apprenticeship was out, he was a good mathematician and had a considerable store of scientific knowledge.

Mr. Walker was well known for his skill as a mechanic, and he used to tell with pride how his master sent him to various mills in Leeds to put machines in order when other men of about twice his age had failed to do so.

Soon after he was twenty-four years of age, he went to Belfast to be manager of the works of Messrs Combe & Dunfield (now Combe, Barbour, & Combe, Limited). He left these works in the latter part of 1847, and returned to his native district with a view to working as an ordinary engine-fitter. He was anxious to devote his mind more fully to the acquisition of mathematical and mechanical knowledge. Years afterwards he stated that he found at that time that having the direction of a large works prevented his gaining the knowledge that he felt he so much needed, and he left Belfast at an immediate sacrifice of position and means. At a later date he became foreman at Messrs. Kitson, Hewitson, & Thompson's works (now Messrs Kitson & Co.), where he afterwards acted as manager.

In the year 1851 he invented several important appliances for making forgings at a reduced cost. In the year 1860 he patented (along with the late Mr. William Hewitson) a very ingenious self-acting motion for a double-acting steam-hammer, doing away with the noisy and destructive tappet motion then in use, and introducing one approaching more nearly the gliding motion of the eccentric of the steam-engine. Many steam-hammers have since been made on this system. At the Paris Exhibition of 1867, Mr. Walker received a medal for his invention. He also invented the now well-known wrought iron wheel for traction engines, instead of the old wooden wheel with a metal tyre, and the frame slotting machine, now also universally used. In the year 1862 he commenced business as a manufacturing engineer at the Goodman Street Works, Hunslet, Leeds, giving special attention to, and earning an important reputation for, special hydraulic appliances and for machinery used in the making

of iron and steel. As early as 1863 he proposed making a forging press for a Sheffield firm, to be used instead of a steam-hammer. The proposition was not accepted at that time, and it has only been during the past few years, since the masses of steel to be dealt with have gradually become so great, that the superiority of the press over the hammer has become recognised, not only for working the steel into form, but for pressing it to the very core and making it denser, tougher, and stronger. In this direction he attained so much success that his firm has made forging presses for many European Governments, and for a number of the largest works in this and other countries.

Mr. Walker made the first hydraulic press for bending armour plates, and has since supplied it to some of the largest works in the world.

Mr. Walker gave early attention to improvements in Bessemer machinery, and on the introduction of the basic process, he made the first converters and hydraulic machinery, and appliances for rolling weldless tyres, as well as reversing apparatus for rolling-mills. He was one of the earliest, if not the first, to propose making Bessemer compound blowing engines, with the result of saving some 30 per cent. in the fuel, and the first compound reversing rolling-mill engines were made by his firm. He was also the first to introduce the separate condensation engine for taking the exhaust steam of one or more engines, and he was the introducer of the three-cylinder blowing engine for cupolas and smith's fires, which has to a very great extent, owing to its great economy and efficiency, replaced fans and other blowers.

Mr. Walker had at different times carried out many improvements in hydraulic cranes, the most notable being his patent double ram-centre or ingot crane for economising water. The original cranes of this type were plain centre ram cranes, the water either acting on the bottom of the ram, or, the ram being made of two different diameters, the water, pressing on the concentric area, raised the jib and the load. This arrangement was wasteful in pressure of water, as it necessitated power to lift not only the load, but also the dead weight of the jib. Mr. Walker employed the centre ram as a guide to take the strain only, and he introduced two side rams, one in constant communication with the accumulator, nearly balancing the dead weight, and the other under the control of the workmen by means of a valve. Cranes on Walker's patent double ram system have been supplied to nearly all the large steelworks and arsenals. The latest mechanical achievement of Mr. Walker was the combined vertical and horizontal press for forg-

ing steel slabs and ingots. Increase in the pressure of steam, and in the sizes and speeds of ships, brought about larger and thicker plates, necessitating much larger ingots and a higher quality of steel. Mr. Walker early recognised the absolute necessity of working the plate ingots on the edge as well as on the flat, and the horizontal and vertical forging press was the outcome of this necessity. On Walker's system, plate ingots of any size can be squeezed horizontally and vertically, the ends cut off and the slab cut into pieces with practically no hand labour, the quality of steel being improved, and the waste greatly lessened.

In the year 1880, Mr. Walker read a paper before the Institution of Civil Engineers, entitled "Machinery for Steel Making by Bessemer and Siemens Processes," and obtained the Telford Medal. In the year 1885 he was a member of the jury of the International Inventions Exhibition, of which His Royal Highness the Prince of Wales was president, and Sir Frederick Bramwell chairman; and he received a certificate and medal for services rendered. He attended regularly, and frequently spoke at, the meetings of the Iron and Steel Institute, and of kindred bodies.

Mr. Walker was a magistrate of the borough of Leeds, and it may be mentioned that when his name was placed upon the Commission of the Peace, the managers and foremen of the works presented him with an address of congratulation. The following is a copy of the address in question :—

"To B. Walker, Esq., J.P., M.I.C.E., M.I.M.E., &c.

"Dear Sir,—It is with great pleasure that we, your foremen, draughtsmen, clerks, and other officials whose names are appended, observe that you have been placed on the Commission of the Peace for the borough of Leeds.

"We feel sure that by this appointment our town has gained a magistrate whose wide experience of life, insight into character, and clear judgment, will make him a great acquisition to the bench.

"We take this as a seasonable opportunity for expressing to you our unbounded personal respect and regard. The majority of us have been in your employ for many years; but whether for a long or a short time, we all have learned to appreciate your high sense of justice, your deep sympathy, and your unvarying kindness towards us.

"We feel that your aim has always been to make us all contented and happy in your service; and that you have succeeded in this is

shown by every one remaining in it while you have honoured them with your confidence.

"Our hope is that greater success and still higher honours are awaiting you, and we also wish long life and happiness to yourself, your wife, and your family.

"We each trust that our fortunes may long be connected with your own, confident in your goodness and kindness towards ourselves, and that your services will continue, as they have hitherto done, to be valued by those who are desirous of calling in the aid of engineering skill, quickness of perception, sound judgment, and integrity of character of the highest order.

"HUNSLET, *2nd July* 1887."

Mr. Walker was a man of great determination and force of character, and to these qualities, coupled with his geniality and uprightness in every phase of life, may be ascribed the success which attended his business career. His geniality found expression for a number of years in giving an annual dinner to the recipient of the Bessemer Medal of the Iron and Steel Institute, and a short time ago the Bessemer Medallists gave him a return banquet, which was a compliment he highly prized.

Always a hard worker himself, he had great sympathy with working men, and in him they always had a friend. In his career and experience of more than fifty years he has seen troublesome times, but he was always treated by the workmen, even by those who thought he was wrong, with the utmost respect.

Mr. Walker was a member of the Council of the Iron and Steel Institute and of the Institution of Mechanical Engineers. He was twice married—in 1847 to Miss Tannett, who survives him. He has two sons and two daughters, who also survive him; the former, Arthur Tannett Walker and Frederick William Walker, being now the sole members of the firm of Tannett, Walker, & Company.

JULIEN D'ANDRIMONT was the son of a well-known manufacturer in Liége, Belgium, and was born in that city on the 27th October 1834. He was a pupil for some time at the Royal Academy of Liége; and subsequently studied at the School of Mines in the same town, obtaining there, on the 25th August 1856, his diploma as an engineer. At a later date he travelled for a considerable time in different Continental countries, with the double purpose of acquiring foreign languages, and

making himself familiar with the conditions of mining and manufacturing industry. Subsequently he became engineer to the great collieries of Hazard, near Liége, to which he also for a number of years acted as managing director, and where he is now succeeded by his son, M. Paul D'Andrimont.

M. D'Andrimont was elected Burgomaster of Liége on 20th August 1867, in succession to M. Piercet, and he continued to hold that position until the 7th May 1870. At a later date—namely, on 21st November 1885—on the retirement of M. Warnant, he was called upon to fill an interregnum as Burgomaster; he continued to do so until the 22nd February 1886. He had, however, for a number of years previously interested himself largely in local affairs, and had, indeed, entered the Town Council of Liége for the first time in October 1860. M. D'Andrimont was elected Provincial Councillor for the Canton de Fleron, and held that position from May 1867 to the 14th June 1890. He was for some years a member of the Chamber of Representatives, from which body he was translated, in 1878, to the Senate, and he has since that year continuously sat in that distinguished assembly.

M. D'Andrimont represented Belgium at the Paris Exposition of 1878, and again at the International Exhibition at Amsterdam. He was for about twenty-five years President of the well-known *Société la Legiar*, and it was recently in contemplation to offer him a banquet to celebrate his long connection with that Society, but his illness and subsequent death prevented the execution of the project.

For many years he had taken a lively interest in the *Société de Littérature*. He took a prominent part in the reception and entertainment of the Iron and Steel Institute at the Liége meeting of 1873, since which time he has been a member of the Institute.

Joseph Musgrave, of Bolton, who died on the 12th January 1891, was born on the 10th March 1812. He was apprenticed to Messrs. Rothwell, Hick, & Rothwell, of the Union Foundry, Bolton, and when Mr. Hick left that firm and built the present Soho Ironworks, Mr. Musgrave went with him in a responsible situation. In 1838 he was appointed resident engineer on the North Union Railway. He designed a skew bridge for the Lancaster and Preston Railway, consisting of a series of arches side by side, receding at the buttress or spring of the arch.

The Globe Ironworks, with which Mr. Musgrave's name is mainly associated, were founded early in the present century by his father, the

late John Musgrave, who up to that time had been engaged in a responsible position at the Soho Ironworks, then belonging to Messrs. Benjamin Hick & Son. In its initial stage the Globe Foundry was of comparatively small dimensions; but thanks to the earnestness of purpose, and the ingenuity and ability displayed by the head of the concern, aided materially in subsequent years by his sons, Messrs. Joseph, Jonathan, John, and James Musgrave, the firm gradually extended its operations, until at the present time the works cover a tract of ground extending from Kay Street into Waterloo Street, and constitute one of the largest engineering establishments in the country. About a quarter of a century ago Messrs. Musgrave & Sons took up a cotton-spinning business, beginning with the erection of the No. 1 Atlas Mill, fronting Chorley Old Road, Halliwell, which was first put into operation about March 1864; and the venture proving successful, fresh mills were added, the last extension to the spinning department being in 1887, when a sixth factory, for about 100,000 mule spindles, was constructed, which has been popularly called the "Jubilee Mill." Since then the firm has also embarked in the manufacture of cotton cloth. Including the employés at the Globe Ironworks, and those engaged in these spinning and weaving concerns, the firm have now in their service nearly 3000 workpeople of all ages. Mr. John Musgrave, sen., died on the 19th of December 1864, at the age of eighty years; and since then Mr. Joseph Musgrave has acted as head of the establishment.

In the question of local railway improvements Mr. Musgrave greatly interested himself at various periods. One of his latest efforts in the direction of railway development was his project for the extension of the London and North-Western line by carrying it over the central part of the town of Bolton, from the present terminus in Great Moor Street to a suggested new site in Church Street, Little Bolton, a distance of about 900 yards. Mr. Musgrave had plans prepared, showing the route of this contemplated addition, together with other particulars; and he brought the matter before the Bolton Chamber of Commerce in November 1887. The project was heartily approved by the Chamber, and strong representations were made to the Railway Directors to induce them to carry out the work, but they declined to accede to the suggestion.

Mr. Musgrave was for twelve years a member of the Halliwell Local Board, during three of which he was chairman.

He was made Justice of the Peace in 1867, and in 1874 he was

returned unopposed as a councillor for the East Ward (in which the Globe Ironworks are situated). In 1877, when that portion of the township of Halliwell which was within the parliamentary borough became incorporated within the municipal borough, he became an alderman, and at a later date, he was chosen president of the Bolton Chamber of Commerce. Mr. Musgrave held the latter office from the formation of the Chamber in 1887 up to his decease, and did good work on behalf of the trading community. In 1880 he was elected Mayor of Bolton. His name has been associated for many years with the Bolton Infirmary and Dispensary, to which he contributed liberally. Mr. Musgrave was elected a member of the Iron and Steel Institute in 1871, and occasionally attended the provincial meetings.

MICHAEL SCOTT was born in Glasgow on the 4th August 1818. He was educated at Fisker's Academy, and afterwards attended the lectures of Professors Graham, Wilson, and Gregory at Anderson's College, Glasgow, where he distinguished himself for his regular attendance. He studied architectural and mechanical drawing with great interest, and became a good draughtsman. He evinced a taste for mechanical engineering, and was articled as a regular working apprentice. The firm to which he was first apprenticed appears to have given up business shortly afterwards, but he served a regular period of pupilage under Mr. Starke, Glasgow, as mechanical engineer, then on the Ayr Railway, and afterwards under Messrs. Caird & Co., Greenock, as a marine engineer.

Whilst studying shipbuilding and marine engineering, in order to gain marine experience, he took employment as an assistant engineer on one of the steamers running between Glasgow and Liverpool in 1843.

Soon after this an assistant engineer was wanted for the Bootle Waterworks, near Liverpool, and Mr. Scott applied for and obtained the appointment. In 1846 he became engineer-in-chief to the company, and successfully completed the undertaking. When the waterworks were purchased by the Corporation of Liverpool in 1847, he was unanimously appointed resident engineer, and held that office till the end of 1849, when he proceeded to London, and began business on his own account as a civil engineer. One of his first engagements was the superintendence, as resident engineer, of the construction of extensive harbour works at Goole, which he had designed. In 1851 he was consulted by the Corporation of Swansea in connection with the water supply for that town, and the bill authorising the works re-

commended in his report received the royal assent on the 30th June 1852. About this time he invented an apparatus for laying large masses of concrete under water, everything being done by divers.

From 1856 to 1860 he was engaged as contractor, under Mr. James Abernethy, in the construction of the Port of Blyth breakwater.

The steelworks at Hallside, near Cambuslang, in Lanarkshire, were erected on plans supplied by the late Sir William Siemens, and carried out under Mr. Scott's directions, the latter having also been the first general manager and secretary of the company.

Mr. Scott took great interest in matters connected with naval warfare and defence, and read papers on these and cognate subjects before the Royal United Service Institution, the Institution of Naval Architects, the British Association, and elsewhere.

Mr. Scott commenced his professional career as a marine engineer, and a great portion of the second volume of his "Occasional Papers" is devoted to Naval Architecture. He claimed to have originated and first made known the *Inflexible* type of ship.

Several papers have been contributed by Mr. Scott to the Proceedings of the Iron and Steel Institute, of which he became a member in 1875. His first paper, on "Improved Casting Arrangements for the Siemens-Martin Process," was read in 1876; his second, also on "Steel Casting Apparatus," was read in 1878; and his third and last, on "Hydraulic Machinery for Steel Works," was read in 1881. For a number of years Mr. Scott was a regular attender at the meetings of the Iron and Steel Institute, and he always took a keen interest in any matter pertaining to the development of the open-hearth process, whether communicated through the "Proceedings" of the Institute or otherwise.

JORGEN DANIEL LARSEN was born on the 26th September 1833, and was educated at the Polytechnic School at Copenhagen. Having received an engineering training, he was employed from 1858 to 1859 on the Newcastle and Maitland Railway, New South Wales, as contractor's resident engineer, and from 1860 to 1862 he was in the Roads and Bridges Department in the Northern District of New South Wales as a Government assistant engineer. He then spent some time in the United States for the purpose of studying the systems of street tramways. From 1866 to 1868 he was engineer to the North of Europe Land Mining Company, for whom he designed and carried out works. From 1869 to 1873 he was resident engineer to the London

Tramways Company, and laid out and superintended the construction of all its lines. He also acted in the same capacity for the Pimlico, Peckham, and Greenwich Tramways Companies, and had charge of the construction of the tramways in Cardiff, Belfast, and Plymouth. He was consulting engineer for the tramways in Madrid; and from 1874 to 1879 was engineer for the Paris tramway lines on both the north and the south sides of the Seine. In 1879 he was engaged in reporting on coal farms in Johannesburg. From 1881 to 1884 he was resident engineer on, and superintended the construction of, the Calcutta tramways for Mr. Hopkins. After visiting Melbourne to examine and report on the tramways in that city, he became engineer to the newly-formed Johannesberg Tramways Company, and made all the necessary surveys and plans, prepared specifications for plant and rolling stock, and superintended the construction of some three or four miles of tramway. Mr. Larsen in the month of March had a paralytic seizure, which terminated in his death on April the 20th.

Mr. Larsen became a member of the Iron and Steel Institute in 1877. He was also an Associate Member of the Institution of Civil Engineers, from whose "Minutes of Proceedings" the foregoing details of his career have mainly been abstracted.

ROBERT JAMES RANSOME was born on 27th June 1830, and had consequently nearly completed his sixty-first year when he died in June 1891. He was the eldest son of a well-known Suffolk man, the late Mr. James Allen Ransome. The deceased's mother was the second daughter of the late Mr. James Neave, of Fordingbridge, Hants, and of St. Helen's Lodge, Ipswich, and Mrs. Henry Footman. The late Mr. Ransome was educated at Ipswich, where, and at Yoxford, he passed his early years, and it was on September 30, 1845, that, choosing to follow in the footsteps of his father as an agricultural engineer, he became apprenticed for a term of seven years to the rising firm of J. R. & A. Ransome. At this time the nucleus of the now world-known Orwell Works had its location in the Old Foundry Road, Ipswich, and it was during the apprenticeship of the subject of this memoir that the Orwell Works, which have so largely contributed to the development and prosperity of the town, were opened in 1849. Subsequent to the completion of his servitude with his father and uncle, Robert James Ransome became manager of the foundry department, and held this post for a considerable

period, until, in 1869, animated by the solid business advice of his father, the establishment of the Waterside Works was determined upon. The contingent erection of the noble pile of business premises and workshops on the opposite banks of the Orwell was watched with interest by the inhabitants of the town generally, and the wisdom of the step has been fully verified by the large measure of success which has followed during the twenty-two years of their existence. Mr. James Allen Ransome himself, without in any sense dissociating himself from the Orwell Works, was a partner with his son in the new undertaking, and they were also joined by Mr. R. C. Rapier. The *raison d'être* for the existence of the Waterside Works was to manufacture railway plant of all descriptions, thus avoiding all probability of clashing with the productions of the original firm from which the new venture sprang.

Their first great work, having international bearings which for all time will link Ipswich with the civilising innovations introduced into China, was the building by Messrs. Ransome & Rapier of the engines, and the laying down of a large part of the plant, for the first railway in the Celestial Empire. This task was executed with skill and enterprise, which gained recognition on all hands; and although subsequently the "powers that be" of China became adverse to the further development of their immense country through the medium of railway communication, it stands on record that the capital of Suffolk led the way in this important direction. Besides the general business of supplying railway plant adapted to all climes and countries, the Waterside Works have built a great many Titan cranes, *i.e.*, cranes of very large size for constructing breakwaters.

The late Mr. Ransome took a prominent part in developing the productive capacity of the Waterside Works, which now cover an area of eight acres, and employ some five hundred hands.

The late Mr. Ransome succeeded Mr. Grimwade as a Councillor for St. Clement's Ward, Ipswich, in 1870, without opposition; and in 1871, when his term of office had expired, he was re-elected without opposition, in conjunction with his colleague, the late Mr. Ebenezer Goddard. Three years later, however, there was a contest, following upon the Conservative spurt, which led to the return of two Conservative members to Parliament. The St. Clement's Conservatives ran Messrs. A. Cobbold and F. A. Christie against the outgoing Liberal Councillors; and, sharing in the changed political conditions as regarded

Imperial representation, the Liberals were defeated. For fifteen years afterwards he was continuously returned unopposed.

Mr. Ransome was a man of few pleasures; he followed the "gentle craft," and was for many years a useful as well as a successful member of the Gripping Angling Society. In his younger days he was an enthusiastic entomologist, and his collection of butterflies, moths, &c., is said to be perhaps the best in Suffolk. He took great delight in his work, and especially in making a "good job." In all things he was a man of good heart, fine disposition, and equable temper.

The late Mr. Ransome married, some thirty-seven years ago, Miss Taylor, daughter of the late Mr. William Taylor, shipbuilder, of Woodbridge. Four sons and five daughters were the issue of the marriage.

THOMAS RICHARDSON, head of the well-known marine engineering works at West Hartlepool, was the son of a wood contractor under the Earl of Durham, who, at a later date, became a shipbuilder at the Hartlepools. To this business that of marine engineering was added in 1838, and his son Thomas was placed in the new works at the age of seventeen. At the time of his father's decease in 1850, Thomas Richardson became the head of the engineering works, and has since largely developed their productive capacity. The first marine engine constructed at these works was built in 1851, but for a number of years previously they had been occupied with the building of locomotive and land engines. The Hartlepool Works have been distinguished in the history of triple expansion engines, having adopted that system at an early date, and applied it within recent years on a large scale.

During the year preceding the decease of Mr. Thomas Richardson, the works of which he was the head produced as many as thirty-three sets of triple expansion engines and boilers, of 45,000 h.-p., as well as 132 crank and propeller shafts. This is one of the largest, if not quite the largest, marine engine h.-p. produced by a single establishment in the United Kingdom, and it may be taken as an evidence of the enterprise of the firm, and of its success.

Mr. Richardson was elected to represent the Hartlepools in Parliament in 1874. Since then he has been returned for the same constituency four several times, and has sat altogether for eleven years as

Member for that important borough. In politics he was a Liberal. He took an active interest for many years in local affairs, and acted as one of the Port and Harbour Commissioners.

In 1843 he married a Sunderland lady, by whom he has a family of four sons and two daughters. He was a member of the Institution of Naval Architects, and was one of the original members of the Iron and Steel Institute.

WILLIAM JOHN was born at Narberth, in Pembrokeshire, and was educated in the Royal Dockyard at Pembroke, and at the Royal School of Naval Architecture and Marine Engineering. He was one of the most esteemed and distinguished students of the latter school.

After leaving the Royal School of Naval Architecture in 1867, Mr. John was employed for several years in the construction department at the Admiralty. Much of his work there consisted of original investigation into the effects of the many modifications that were then being introduced into the designs of war-ships. It was thus that he was led to put the results of calculations of the righting moments of ships at various angles of inclination into the form of a curve, and thus to give a continuous representation of the stability at all angles. This was applied to the case of H.M.S. *Captain*, and the deficiency of stability possessed by her was thus disclosed only a few days before she was lost. In 1872 Mr. John left the Admiralty for the service of Lloyd's Register Society. A number of papers were read by him before the Institution of Naval Architects between 1872 and 1881, when he left Lloyd's to become the general manager of the Barrow Shipbuilding and Engineering Company. These papers are on "The Strength of Iron Ships," read in 1874; on "The Strains of Iron Ships," "The Stability of Ships," and "The Transverse and other Strains of Ships," read in 1877; on "The Royal Naval College and the Mercantile Marine," in 1878; and on "The Cellular Construction of Merchant Ships," in 1880. During the nine years Mr. John was at Lloyd's, he was the scientific assistant to Mr. Martell, the chief surveyor; and there, as at the Admiralty, he was largely employed upon original investigations, such as those relating to the strength of ships, and the strains to which they are subjected at sea, the strength of masts, rigging, &c. Mr. John's work upon the latter subject was embodied in a report published by Lloyd's Register Society, "On the Masting of Ships."

Mr. John was a Fellow of the Royal School of Naval Architecture and Marine Engineering, a member of Council of the Institution of Naval Architects, and a member of the late Board of Trade Committee on Life-Saving Appliances in Ships. He became a member of the Iron and Steel Institute in 1879, and spoke at several meetings on shipbuilding subjects.

Robert George Tosh was the son of Mr. George Tosh, manager of the North Lincolnshire Ironworks, near Doncaster. He went through the usual course of the Royal School of Mines, in chemistry, metallurgy, and mineralogy, and afterwards, for a period of ten years, acted as chemist and assistant manager to his father at the works of the North Lincolnshire Iron Company. In January of the present year (1891) he left this country for the United States, with the intention of settling down in the newly-developed iron district of the South. In July he was attacked by typhoid, and after a few days' illness died at Middlesbro, Kentucky, at the early age of thirty-one. He became a member of the Institute in 1881.

George Adams was born at Broseley, in Shropshire, on the 13th of March 1829. His father was a barge-owner on the Severn, trading between Worcester and Madeley, at that time the centre of the Midland iron industry. Mr. Adams' first occupation was as turner of a potter's wheel at the Coalport China Factory. In 1838, at the request of Mr. George Jones, of the Spring Vale Ironworks—a relative of Mr. Adams—his father came over and settled in Staffordshire, taking occupation at Spring Vale. Here Mr. Adams received a practical education in the manufacture of iron, and in 1850 he accepted employment under the firm of Messrs. Rose, Higgins & Rose, the celebrated ironmasters of Bradley, where he remained as stocktaker for eight years. While there he aided Mr. James Rose in the compilation of a (new) "Guide to the Iron Trade," which is still regarded as a standard work of reference. In 1858 Mr. Adams was appointed sole manager to Messrs. Wright & North, of the Monmoor Ironworks, remaining in that position until 1872. While he was filling this capacity he started business on his own account, and founded in 1867 the present Mars Ironworks. In 1872, feeling that he could no longer maintain the two positions, Mr. Adams devoted himself entirely to his own works at Ettingshall, which have now grown into one of the largest and most productive ironworks in South Staffordshire.

On leaving Messrs. Wright & North, Mr. Adams received an

address from the workpeople in which the following sentence occurs:— "We feel sure, in severing the tie that has now existed between us for fourteen years, we are parting with a dear, much-valued friend, who was ever ready to lighten the burden of toil by kind encouraging words, and in distress to assist and relieve the afflicted; and who, by impartial conduct between master and man, maintained that relationship in a manner deserving of our highest praise and gratitude."

Mr. Adams' connection with his workpeople was ever of the most cordial character. His employés realised that their interests, safe in his hands, were identical with his, and his with theirs. Strife between them was of the rarest occurrence, and when others were disputing they were at work.

He was connected with several trading concerns, amongst them the Aldridge Colliery Company, of which he was a vice-chairman and director, and in which he had always taken a very active part. A few years ago, Mr. Adams erected a galvanising plant, which now converts large quantities of black sheets into galvanised iron.

Six or seven years ago Mr. Adams had a severe illness, but gradually he regained his strength, and to all appearance his health was re-established. Mr. Adams was a talented musician, and the founder of the Wolverhampton Harmonic Association. He was also a member of the County Council as representative of North Bilston, and in 1881 was elected a member of the Wolverhampton Town Council. He became a member of the Iron and Steel Institute in the year 1870.

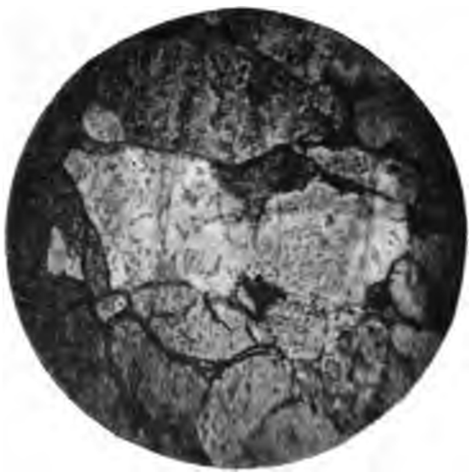
Microscopical Structure of Steel.

EXTRA-MILD STEEL.

VERTICAL ILLUMINATION.

ANNEALED AT 1015° C.; ETCHED BY NITRIC ACID.

MAGNIFIED 300 LINEAR.



HARD STEEL.—HAMMERED.

ETCHED BY NITRIC ACID. MAGNIFIED 300 LINEAR.

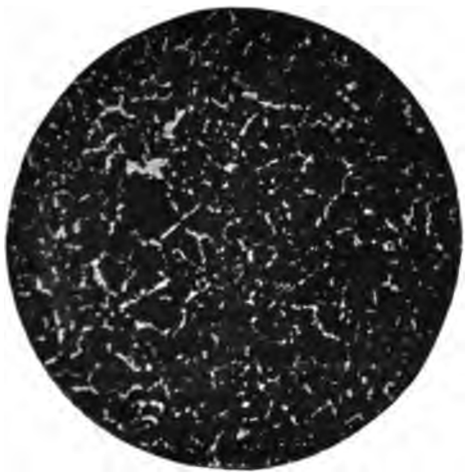
Microscopical Structure of Steel.

MEDIUM STEEL.—HAMMERED.

VERTICAL ILLUMINATION BY TRANSPARENCY.

MAGNIFIED 45 LINEAR.

Carbide *in situ* left by a thin slice, after attacking by Abel's chromic liquor.



EXTRA-MILD STEEL.—HAMMERED.

ETCHED BY NITRIC ACID.

Vertical Illumination—Slightly Etched.

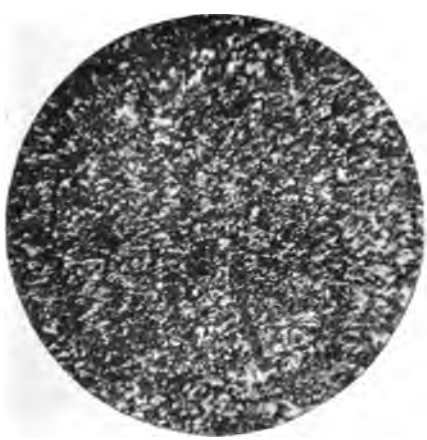
Microscopical Structure of Steel.

ETCHED BY NITRIC ACID. MAGNIFIED 45 LINEAR.

EXTRA-MILD STEEL—HAMMERED.

Oblique Illumination—Slightly Etched.

Strongly Etched.



Microscopical Structure of Steel.

ETCHED BY NITRIC ACID. MAGNIFIED 45 LINEAR.

MEDIUM STEEL.

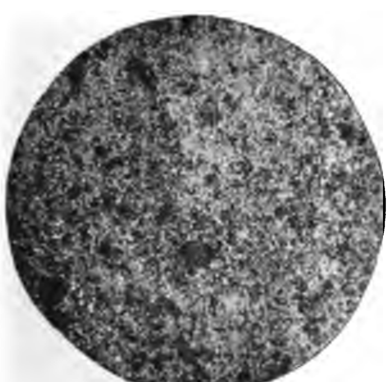
Vertical Illumination—Slightly Etched.

HAMMERED.

ANNEALED AT 750° C.

HARD STEEL.—HAMMERED.

Vertical Illumination—Slightly Etched.



Oblique Illumination—Slightly Etched.

Microscopical Structure of Steel.

ETCHED BY NITRIC ACID. MAGNIFIED 45 LINEAR.

EXTRA-MILD STEEL.

ANNEALED AT 1015° C.

Vertical Illumination—Slightly Etched.

EXTRA-MILD STEEL. MEDIUM STEEL.

ANNEALED AT 1115° C.

Vertical Illumination—Slightly Etched.

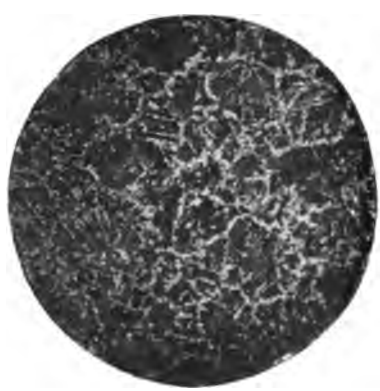


PLATE VI.

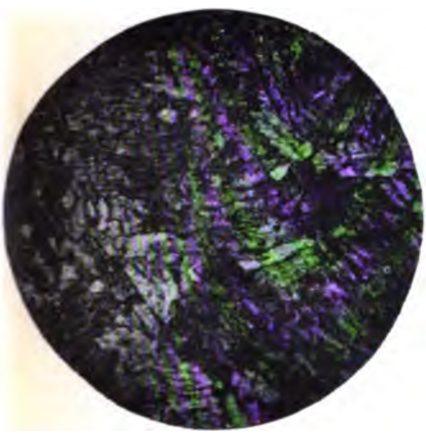
Microscopical Structure of Steel.

ETCHED BY NITRIC ACID. MAGNIFIED 45 LINEAR.

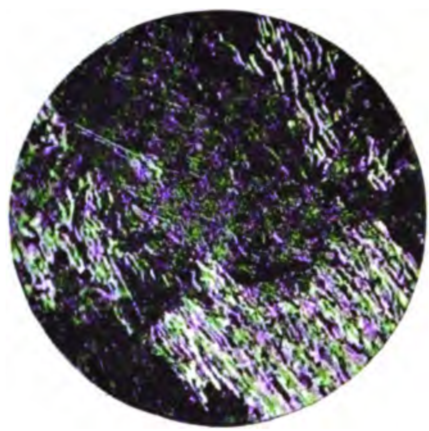
EXTRA-MILD STEEL.

ANNEALED AT 1330–1390° C.

Vertical Illumination—Slightly Etched.

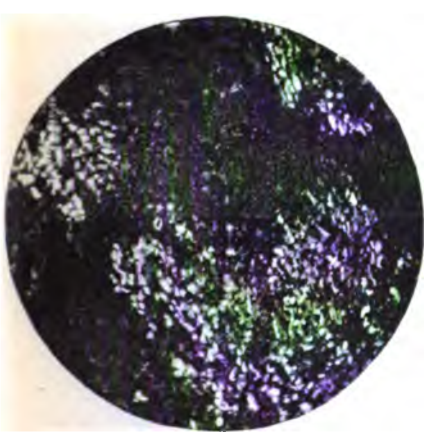


Oblique Illumination—Slightly Etched.



EXTRA-MILD STEEL.

Oblique Illumination—Strongly Etched.



MEDIUM STEEL.

Vertical Illumination—Slightly Etched.

Microscopical Structure of Steel.

ETCHED BY NITRIC ACID. MAGNIFIED 45 LINEAR.

ANNEALED AT 1330–1390° C.

MEDIUM STEEL.

Oblique Illumination—Slightly Etched.

HARD STEEL.

Vertical Illumination—Slightly Etched.

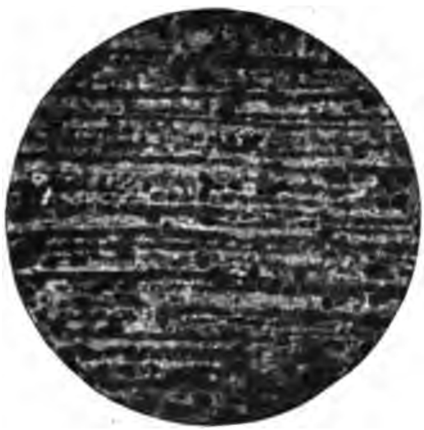
Oblique Illumination—Slightly Etched.

Microscopical Structure of Steel.

ETCHED BY NITRIC ACID. MAGNIFIED 45 LINEAR.

EXTRA-MILD STEEL.—HARDENED.

Vertical Illumination—Slightly Etched.



MEDIUM STEEL.—HARDENED.

Vertical Illumination—Slightly Etched.

Oblique Illumination—Slightly Etched.

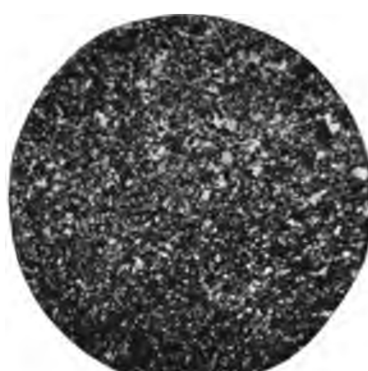
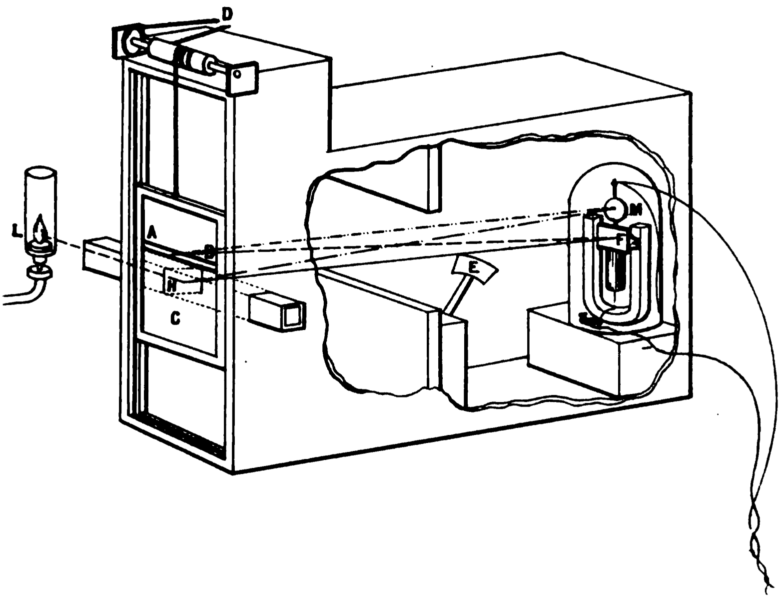


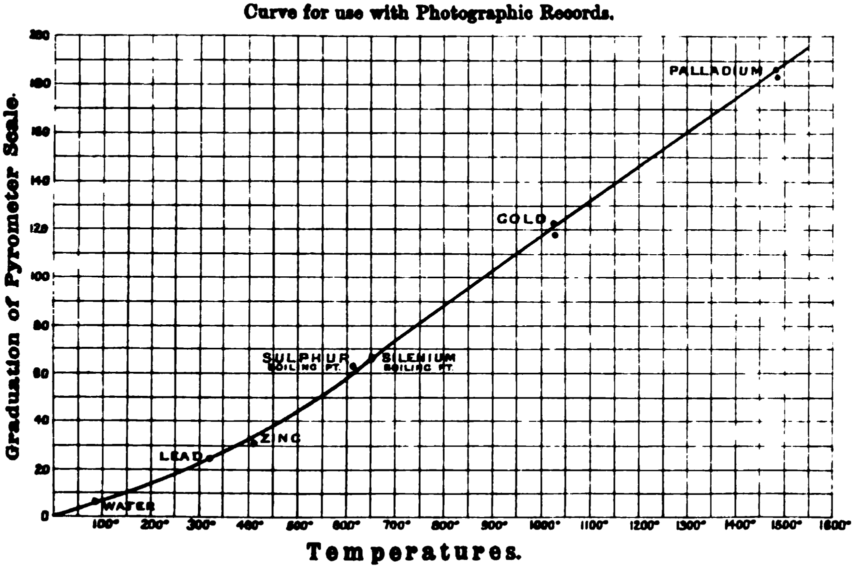
PLATE IX.

TO ILLUSTRATE PROFESSOR ROBERTS-AUSTEN'S COMMUNICATION.



Calibration of Pyrometer.

Curve for use with Photographic Records.



Ballantyne, Hanson & C° Edinburgh & London.

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

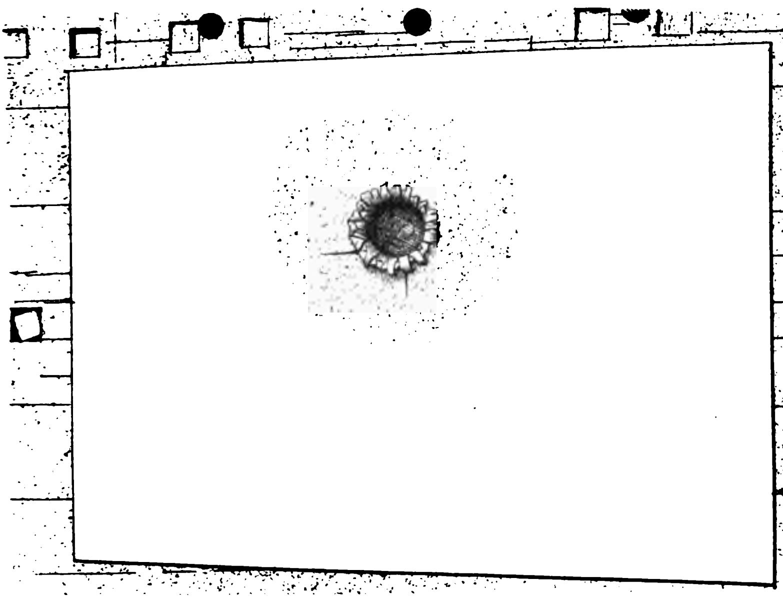


Diagram 1.

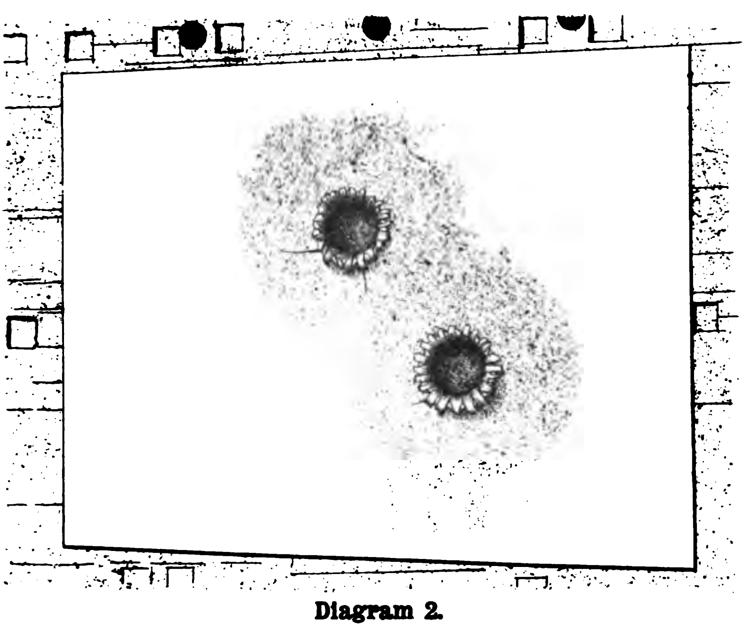


Diagram 2.

Ballantyne, Hanson & Co Edinburgh & London.

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

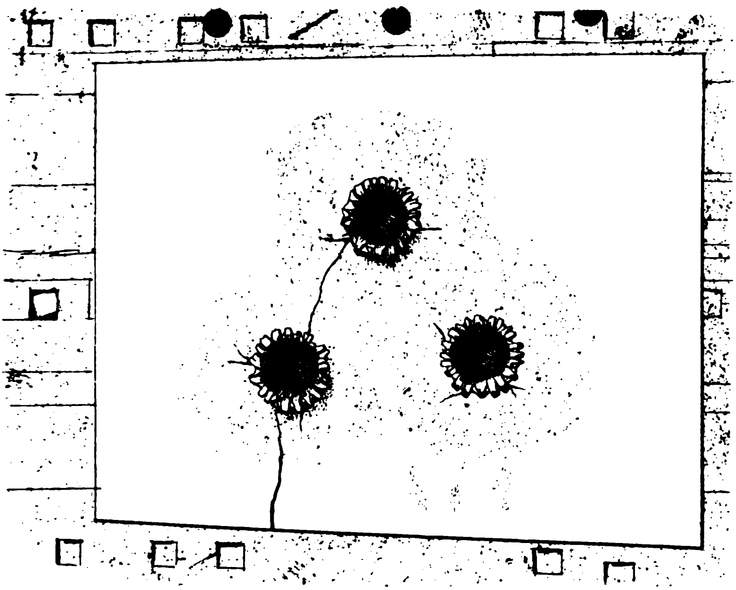


Diagram 3.

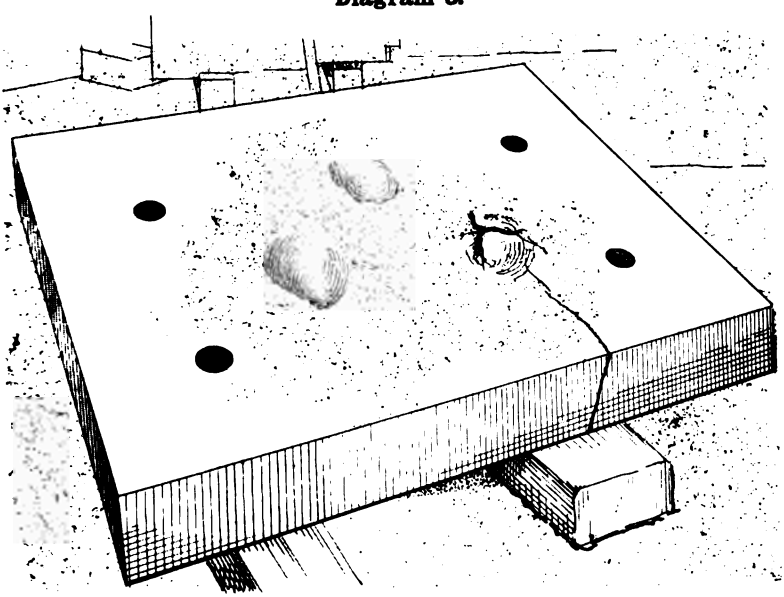


Diagram 4.

Ballantyne, Hanson & Co Edinburgh & London.

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

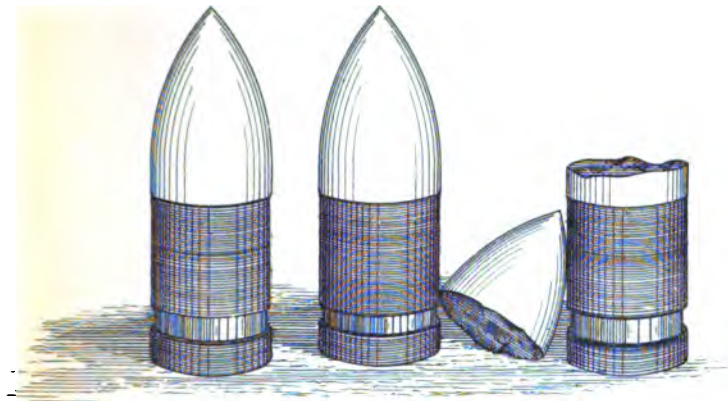


Diagram 5.

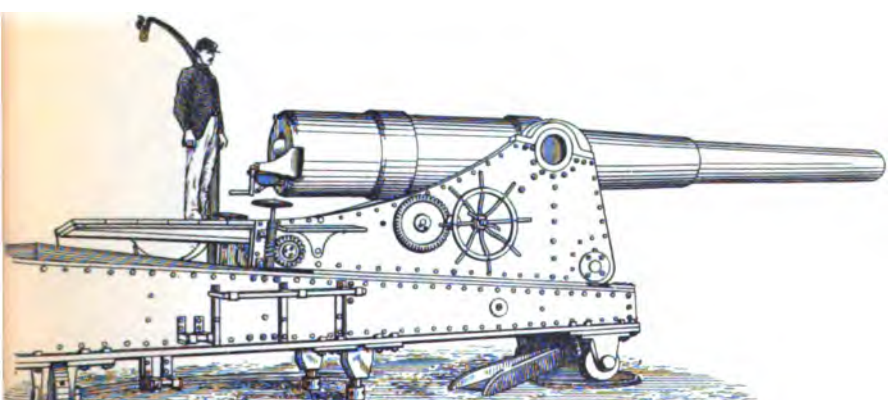


Diagram 6.

Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

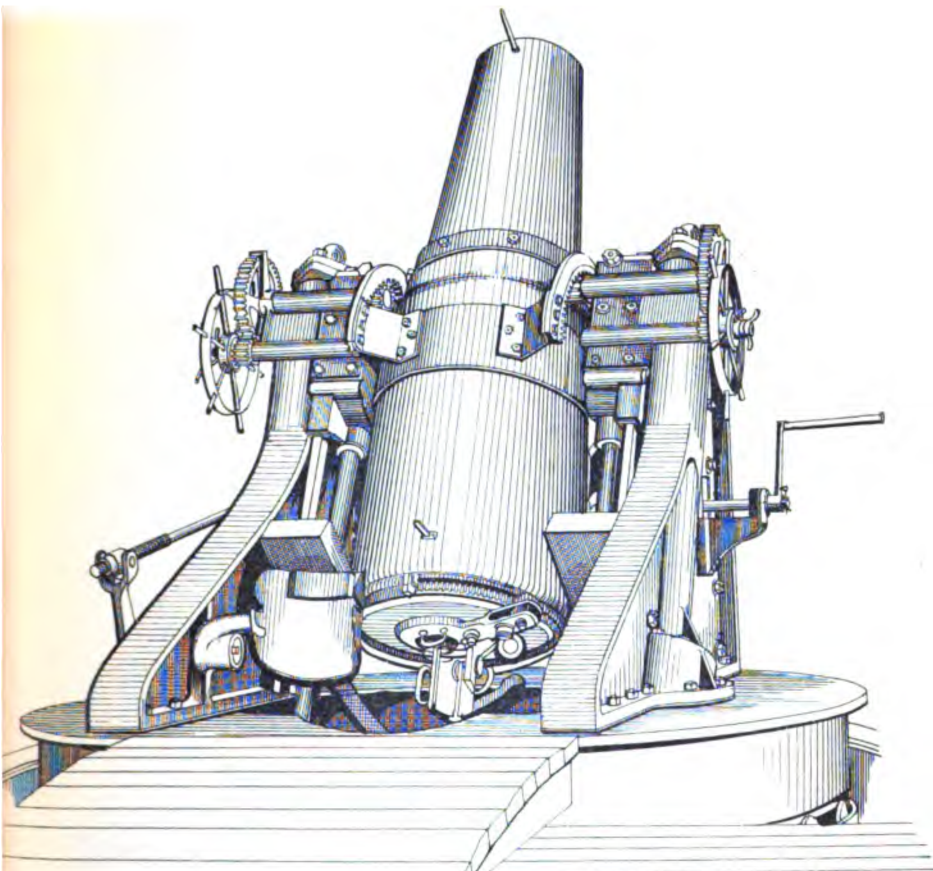


Diagram 7.

Ballantyne, Hanson & C° Edinburgh & London

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

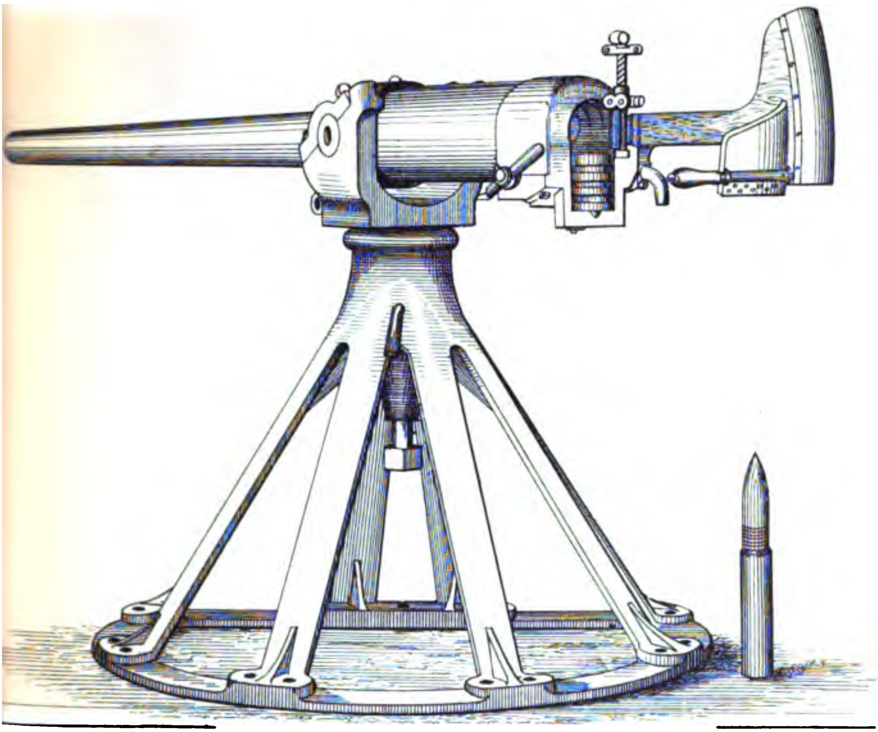


Diagram 8.

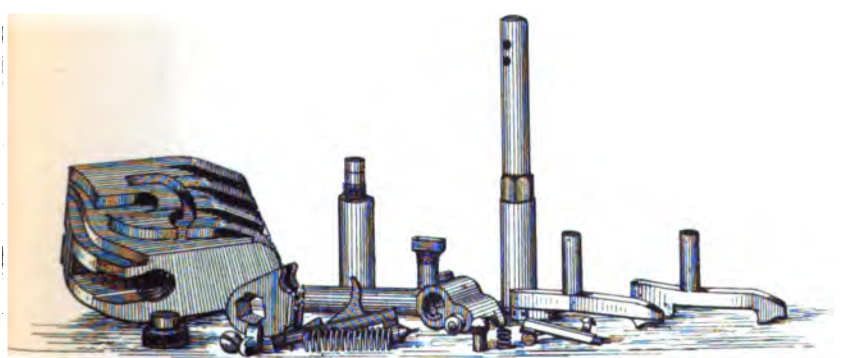
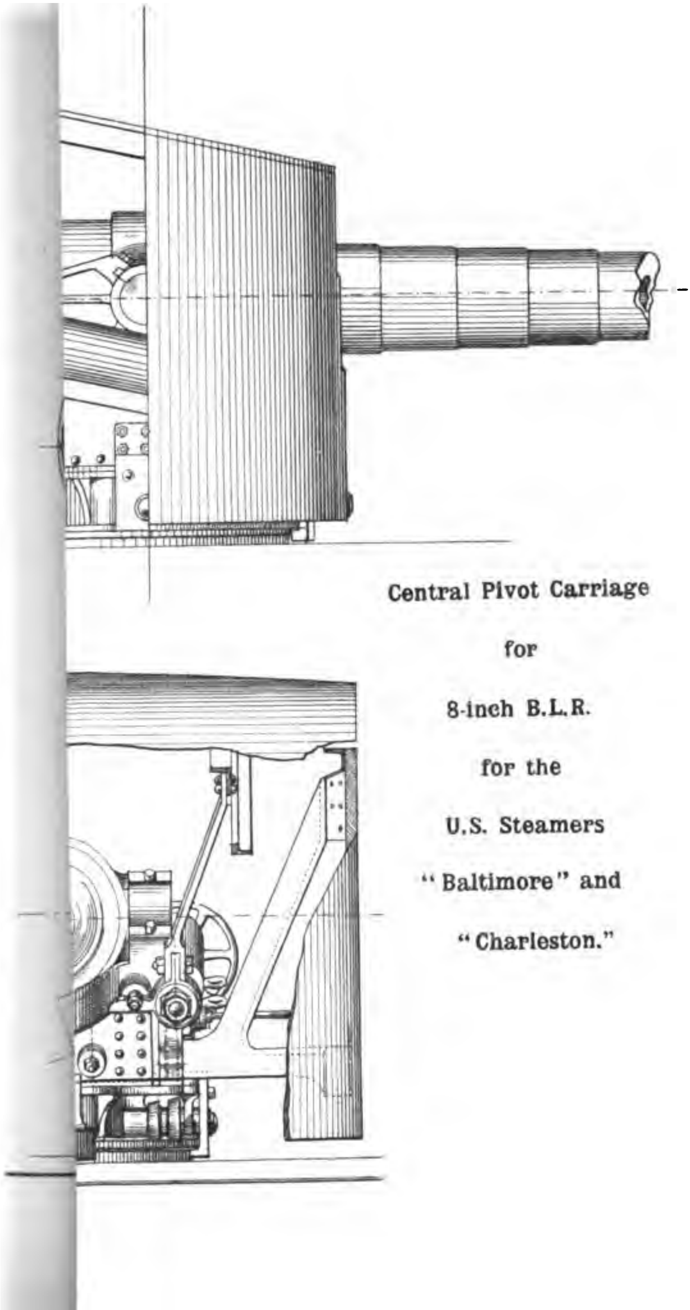


Diagram 9.

Ballantyne, Hanson & C° Edinburgh & London.



Central Pivot Carriage

for

8-inch B.L.R.

for the

U.S. Steamers

"Baltimore" and

"Charleston."

ATE MR. JAQUES'S PAPER ON MANUFACTURE
WAR MATERIAL IN UNITED STATES.

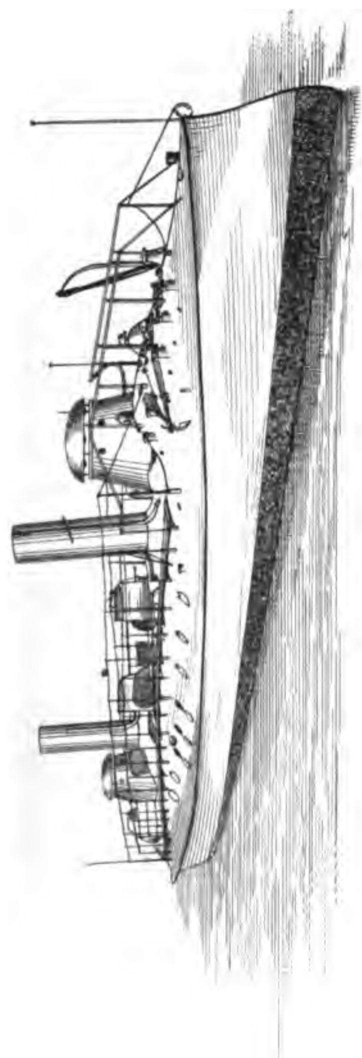


Diagram 11.

U.S.S. Torpedo Boat "Cushing."

Ballantyne, Hanson & C° Edinburgh & London.

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

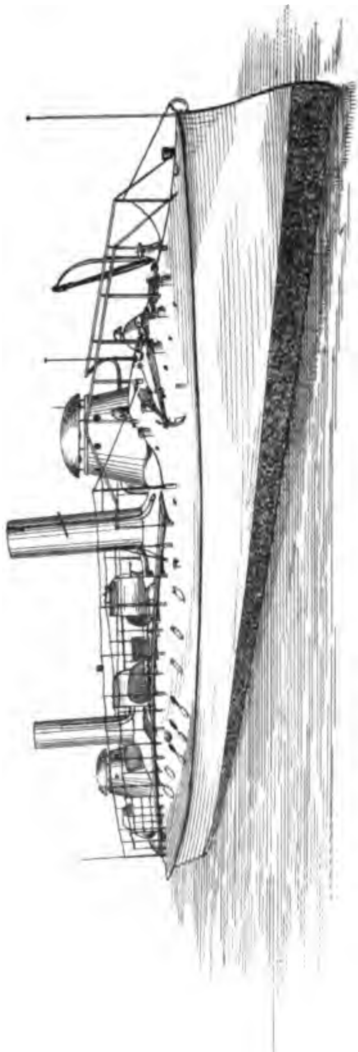


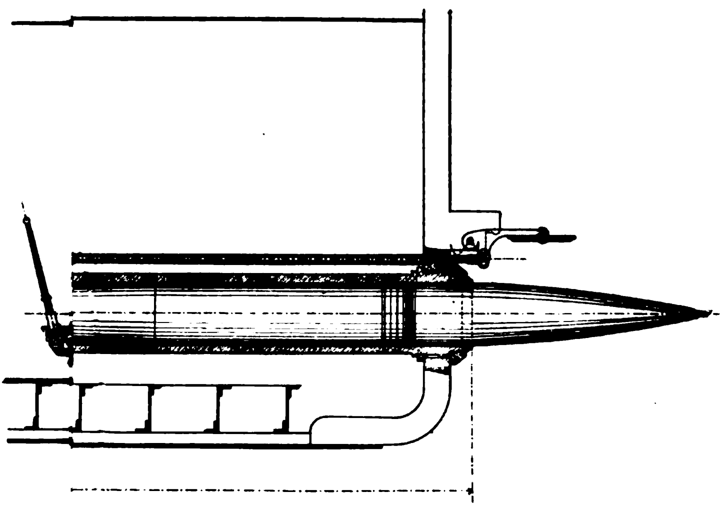
Diagram 11.

U.S.S. Torpedo Boat "Cushing."

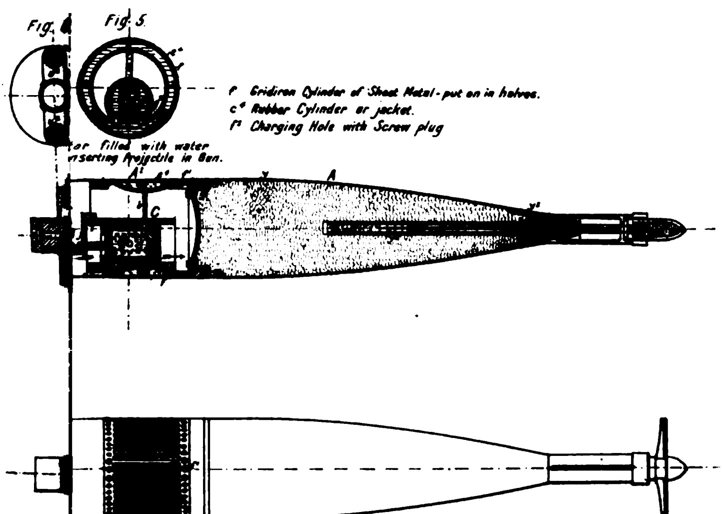
Ballantyne, Hanson & Co. Edinburgh & London.

PLATE XVII.

JRE OF WAR MATERIAL



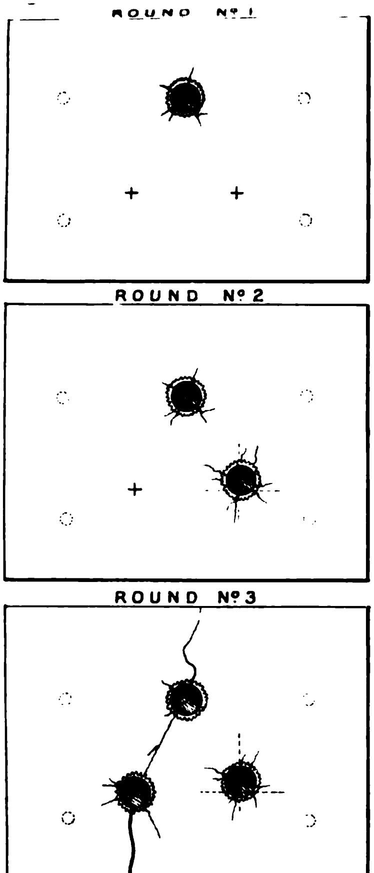
00 pounds.
392 ,,
396 ,,
544 ,,
48 feet.

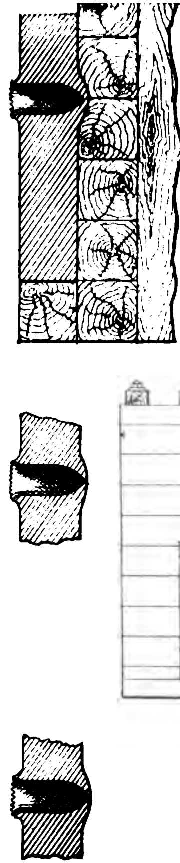


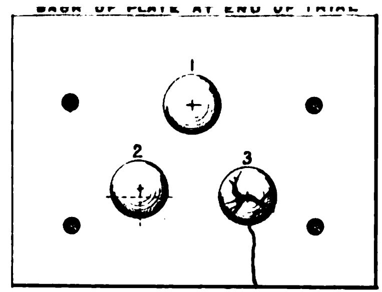
Ballantyne, Hanson & Co. Edinburgh & London.

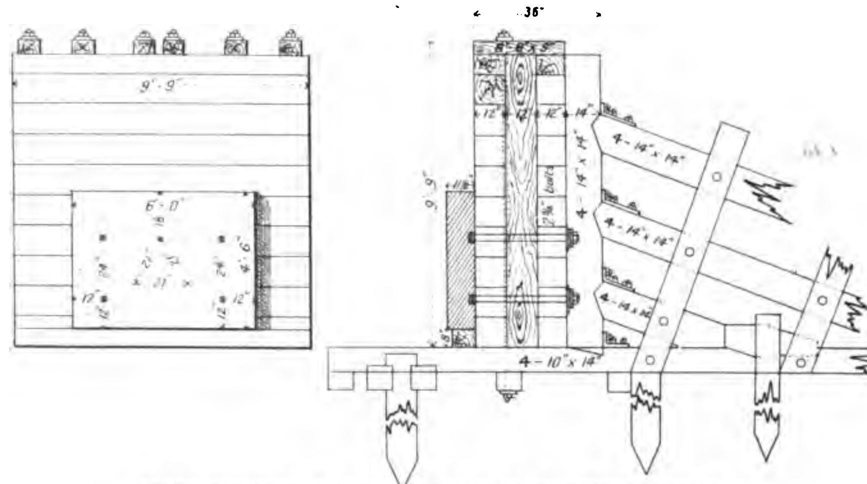
TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

Experimental 11½" Armour Plate.









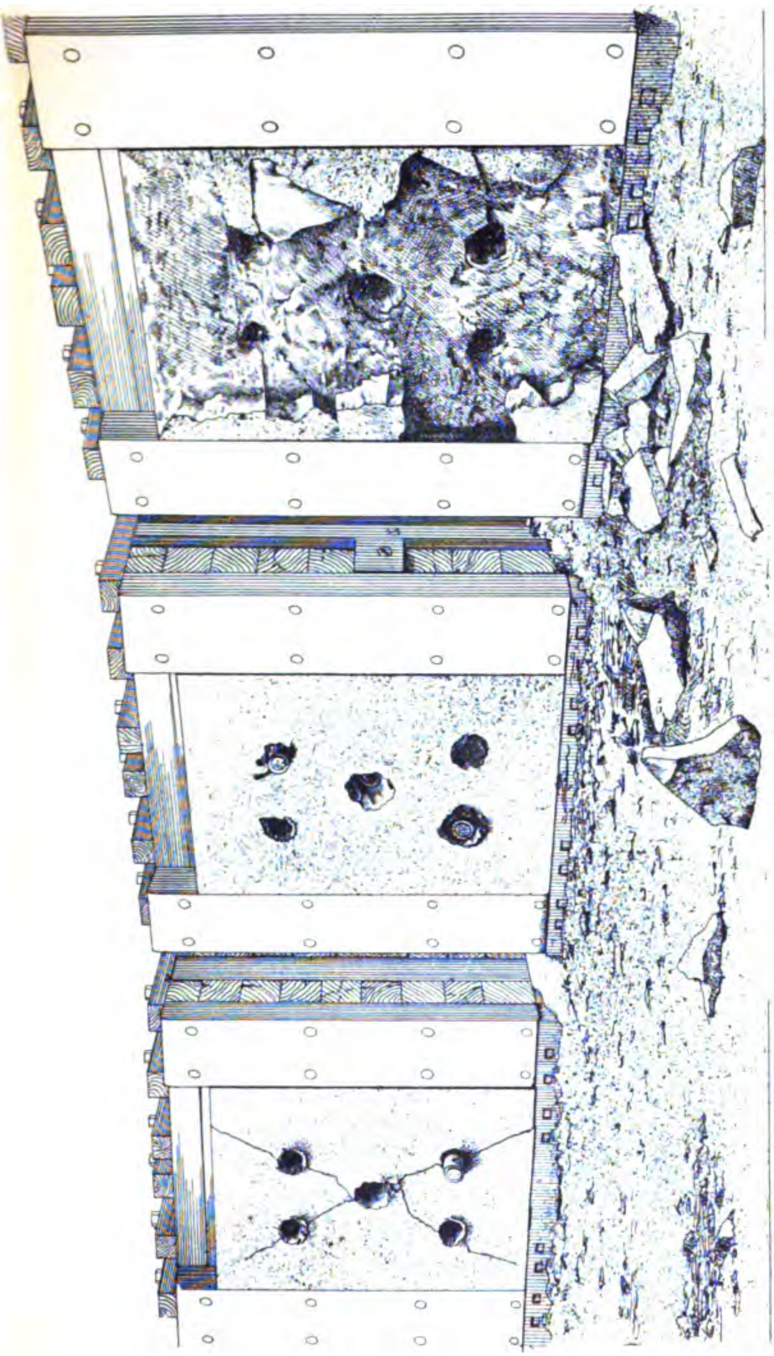
FRONT AND SIDE ELEVATIONS OF TARGET BEFORE ATTACK

Diagram 14.

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE XIX.

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.

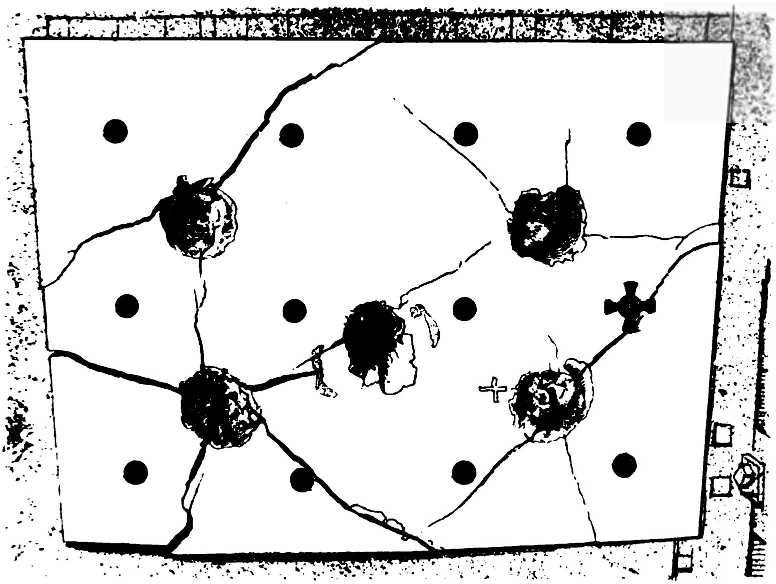


The Creusot Steel, Nickel Steel, and the Cammell Compound Armour Plates.

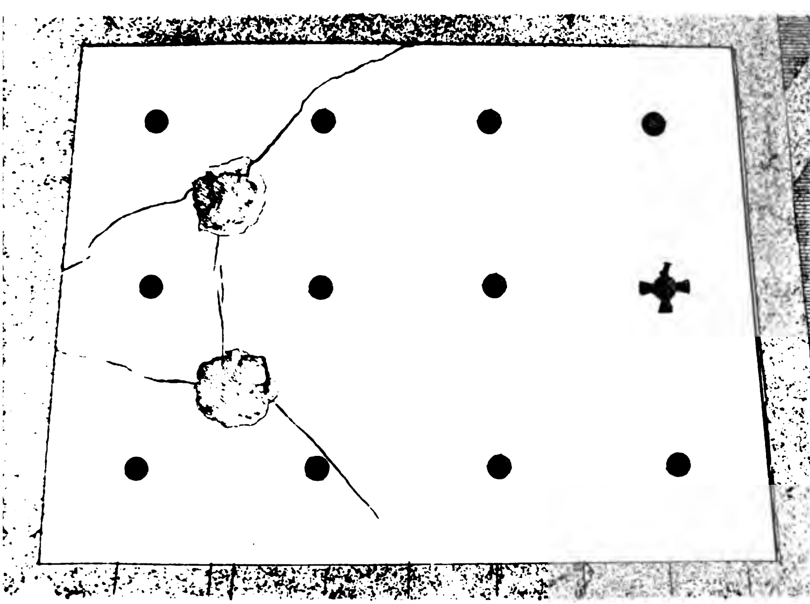
Diagram 15.

Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. JAQUES'S PAPER ON MANUFACTURE OF WAR MATERIAL IN UNITED STATES.



The Harvey Plate. Fifth Shot.



The Harvey Armour Plate. Second Shot.

Recent Armour Plate Trials. **Diagram 16.**

Ballantyne, Hanson & Co. Edinburgh & London.

NOTES

ON THE PROGRESS OF THE

HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

I.—1891.

CONTENTS.

ABSTRACTORS.

EDWIN J. BALL, Ph.D.

BENNETT H. BROUGH, Assoc. R.S.M.

IRON ORES.

CONTENTS.

I.—*OCCURRENCE AND COMPOSITION.*

The Iron Ore Deposits of Leicestershire.—According to Mr. M. H. Mills,* it was not until 1876 that any serious attempts were made to use the iron ore deposits in Leicestershire. In the Vale of Belvoir the soft Keuper sands and the overlying Lias shales lie conformably and dip to the south-east. Farther eastward is found the Marlstone, in an escarpment of hard arenaceous rocks. The workable bed of iron ore, 6 to 9 feet thick, lies on the summit, and with the overlying Oolitic limestone forms an extensive tableland. The bed is, however, very variable in thickness and quality. The author is inclined to believe that some of the iron ore lies in the Oolitic formation, and that it is not restricted to the Marlstone, as is believed by Mr. E. Wilson. There is a continuous outcrop of this rock-bed from Melton Mowbray to Grantham, and all along it there are extensive workings of ironstone by several companies. The workable ironstone is about 8 feet thick with 4 to 6 feet of cover, and rests on ferruginous limestone. Long cuttings are driven, and a train line is laid close to the face. The stone is removed in small iron waggons by a locomotive to a tippler, where it is loaded on to the railway. Refuse is spread behind the face and covered with soil to renew the surface. The stone is not usually calcined, unless it is heavily charged with moisture. The probable extent cannot be estimated, as the bed passes under the newer formations, but a large area will probably be proved in the future, when the proximity of coalfields will render Leicestershire a large iron-producing county.

* *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 28–30.

Iron Ore in Wicklow.—Mr. C. S. Parnell * states that the magnetite lode which supplied the iron furnaces at Clesh two centuries ago has recently been rediscovered at a depth of 100 feet below the surface. At this point it is 30 feet in width, and contains 60 per cent. of iron and 10 per cent. of manganese.

Analyses of Austrian Iron Ores.—Dr. E. Prziwoznik † gives the following analyses of Austrian iron ores :—

	a.	*b.*	*c.*	*d.*	*e.*
Ferric oxide	67·54	69·21	52·64	71·07	70·50
Ferrous oxi	1·67	...	...	. .	...
Manganese oxide	trace	1·84	3·94	4·04	2·77
Copper oxide	trace	trace	...	...	0·01
Alumina	...	2·79	17·51	2·03	0·78
Lime	16·21	7·90	10·20	7·90	0·27
Magnesia	0·34	4·05	3·20	3·86	6·46
Silica	1·15	7·10	9·12	7·05	13·63
Sulphuric anhydride	...	0·30	0·48	0·48	0·96
Phosphoric anhydride	4·57	0·09	0·08	0·06	0·07
Carbonic anhydride	7·80	} 7·30	2·10	1·80	0·70
Carbon	...		0·23	...	0·44
Water	0·80	...	0·50	1·75	1·00
Total	100·08	100·58	100·00	100·04	100·25

a. Red hæmatite from the Austrian-Alpine Mining Company; *b.* spathic iron ore, roasted, from Vordernberg; *c.* and *d.* the same, from Eisenerz; and *e.* the same, from Golbrad. This last also contains 0·136 per cent. of cobalt oxide and 0·525 per cent. of barytes.

Chrome Iron Ore in Lower Silesia.—A considerable deposit of chrome iron has been found in the serpentine occurring between Schweidnitz and Jordansmühl, on the southern slope of Mount Zobten. The deposit was found *in situ* by shoding, some loose stone having been noticed near the Ströbel station of the Breslau-Ströbel Railway. Near the surface it has a thickness of 23 feet, and this seems to increase with depth. The ore was at first mined by open working, but is now being worked by a shaft and levels. The composition of the ore is as follows :—

Cr_2O_3.	Fe_2O_3.	Al_2O_3.	MgO.	SiO_2.
35–42	19–22	19–22	16–18	3–5

The ore contains in admixture variable quantities of magnetite.‡

* *The Echo*, December 18, 1890.

† *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxviii. pp. 402–404.

‡ *Stahl und Eisen*, vol. x. p. 1085.

Iron Ore Deposits in the Banat.—The iron ore deposits occurring in the neighbourhood of Dognacska and of Moravicza were examined in 1883 by the Swedish geologist Sjögren, and later by J. von Halaváts.* The ore deposits occur along the line of contact of crystalline slates and eruptive rocks with a zone of limestone. They exist mostly in the form of separate lenticular deposits of red and brown hæmatites and of magnetite. As a rule, the ore occurring in the Moravicza district is purer than that of Dognacska. Some interesting observations are made as to the comparative influence of changes in the character of the country on the nature of the ore. The annual output is about 100,000 tons.

Discovery of Iron Ore in Spain.—Large deposits of iron ore are stated to have been discovered at Incio, in Galicia. The ore is stated to be of considerable richness and purity. An estimate placed the quantity of ore at 66 millions of tons, but this is believed to be too high.†

Spanish Iron Ores.—F. Gáscue ‡ gives the following analyses of iron ore from Quiros (1, 2, 3), and from Llumeres (4), in the north of Spain :—

	Fe_2O_3.	Mn.	Al_2O_3.	CaO.	MgO.	SiO_2.	P.	S.
1	70·96	trace	1·00	0·56	trace	24·30	0·38	0·22
2	79·54	0·80	1·60	0·62	trace	14·00	0·48	0·60
3	74·40	trace	2·50	2·50	trace	16·20	0·05	0·41
4	72·83	...	7·38	2·00	0·30	14·30	0·48	...

As a rule, the Llumeres ore contains from 16 to 18 per cent. of silica.

An iron ore mined in the neighbourhood of Gijon, and smelted at the Gijon Ironworks, has the following composition §—

Fe_2O_3.	FeO.	Mn_2O_3.	Al_2O_3.	CaO.	P_2O_5.	SiO_2.	Loss.
74·91	0·47	0·20	4·27	0·44	0·88	15·35	2·76

Iron Ore Deposits in Portugal.—The Portuguese coalfields are but small in size, and produce coal of poor quality. The deposits of

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 91-96, 102-106, with illustrations.

† *Revista Minera, Metalurgica y de Ingenieria*, vol. xlii. p. 86.

‡ *Ibid.*, vol. xli. p. 83.

§ *Mining Journal*, vol. lx. p. 1455.

iron ore are, however, according to J. M. Do Rego Lima,* of large size, although there is but little work being done in them. The deposits are three in number—those of Moncorvo, between the Sabor and the Douro; those of Montemoro-novo, Vianna, and Alvito; and those of Odemira and Santhiago-do-Cacem. The Moncorvo district is best worthy of attention, as, although it lies far from the coast, yet its deposits are best known. It is supposed that there are some 40 to 50 million tons of ore, and of this quantity 10 to 15 million tons are ready for transport. The rivers Sabor and Douro could give some 2500 to 3000 horse-power, so as to partly replace the lack of fuel. The importation of iron of various kinds rose from 16,000 tons in 1871 to 55,000 tons in 1888, and this is held to justify the proposal to erect two blast furnaces of 60 to 70 tons capacity.

The ore at Moncorvo gives on analysis—

FeO.	Fe_2O_3.	CaO.	Insoluble.	Water.	P_2O_5.	Total.
12·94	65·85	0·50	16·45	3·95	trace	99·69

and contains 54·95 per cent. of metallic iron. The ore ranges from 28 to 59·2 per cent. of iron, averaging 50 per cent. The blast furnaces could be situated near the railway, and supplied from the mine by a wire-ropeway. The pig iron made could be used for making Bessemer steel, the necessary ferro-manganese being produced from Alemtejo ores; or open-hearth steel could be made with the aid of old Portuguese railway rails. The fuel would be supplied from England or the Asturias, the works being about 75 miles from the mouth of the river Douro.

Grängesberg Iron Ore.—N. Kjellberg † discusses the value of the iron ore from Grängesberg, in Sweden. It is unsuitable for the manufacture of foundry pig iron, and it cannot compete with pig iron imported from England and Scotland. For the manufacture of basic Bessemer pig iron, too, but a small portion of these ores can be used, as most of them contain more than 1·5 per cent. of phosphorus, and as cheap phosphoric tap-cinder is unavailable. All the rich ores, however, are eminently suited for the production of pig iron for the basic open-hearth process.

Phosphoric Iron Ores in Sweden.—Search has been instituted in Sweden, at the cost of the State, for iron ores rich in phosphorus,

* *Algumas palavras sobre las condiçios d'adaptaçao da industria sidurigica em Portugal.*

† *Jernkontorets Annaler*, vol. xlv. pp. 350–388.

and in Norland with success, considerable deposits of such ore having been met with. An experimental blast at the furnace belonging to the Mining School at Filipstadt yielded a pig iron containing from 9 to 13 per cent. of phosphorus, and a slag with as much as 18 per cent. of phosphoric anhydride.*

The Iron Ore Deposits of Naeverhaugen.—Dr. A. W. Stelzner † has made an examination of the iron ore bed between Skjerstad and Foldenfjord in Norway. The rich ores consist of specular iron ore and magnetite, and contain 64·3 per cent. of iron, 0·21 to 0·5 per cent. of phosphoric anhydride, and 0·01 to 0·03 per cent. of sulphur. The author describes the geology of the district, and points out that the poorer ores might easily be concentrated by coarse crushing and jigging.

The Iron Ores of Australia.—In a recent report on the subject of Australian iron ores, the United States Consul at Sydney states that New South Wales is, with the exception of New Zealand, the only colony in the Australian group that possesses extensive iron deposits. These deposits are found at Wallerawang, Lithgow, Mittagong, Mount Lambie, Berrima, Illawarra, and in various other parts of the colony. Both coal and limestone are found in most places near at hand. At Wallerawang there are immense masses and veins of magnetite, with garnet ironstones. There are also rich veins of red and brown hæmatite. Professor Liversidge, who recently made analyses of the iron ores of New South Wales, states that the magnetite ores average 40·87 per cent. of metallic iron, the garnet ironstones 21 per cent., the brown hæmatites from 37·84 to 51·82 per cent., and the claybands 49·28 to 56 per cent. of iron. Vast deposits of brown hæmatite exist near the junction of the Hawkesbury and Wianamatta formations. Large deposits of magnetite are found on the Bogan and Lachlan rivers. On the Southern Railway line there are extensive deposits of brown hæmatite, with coal measures near to them. Brown hæmatite ore is also found in the rich coalfields of Bulli and other parts of the Illawarra district. The ore at Bulli, as well as at Eskbank and Lithgow, is very rich, and averages over 50 per cent. of iron. Bog iron ore, usually of a porous ochrey nature, exists in considerable quantities at Mittagong. The district throughout abounds in deposits of iron, coal, shale, manganese, lime, and fireclay. The shale near Mittagong contains a high

* *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 311.
† *Ibid.*, vol. l. p. 180.

percentage of kerosene. One company occupies 2000 acres of land, upon which there is a proved seam estimated to contain 200,000,000 tons of kerosene shale, besides coal and other minerals. Iron ore exists at Berrima, in the same county as Mittagong, and it is said to be even richer than that found at Mittagong. The Government, on account of the favourable reports of the iron ore seams at Mittagong and other parts of Camden County, have taken steps to ascertain the number of iron deposits, and to define their position, extent, and contents. Various specimens of ore from this county were analysed by the Government analyst during the year 1889, and they yielded from 40 to 62 per cent. of iron. Red hæmatite is also found in abundance in various parts of the colony, particularly in the so-called "red hills" occurring in the New England tin district. It is also found near Sydney and in the Illawarra district. A specimen of this ore gave 90·55 per cent. of ferric oxide, its specific gravity being 4·49. Continuous seams of magnetite from 30 to 40 feet in thickness have been opened up in the Illawarra district, near the railroad, with an abundant supply of coal, lime, and claybands. Iron pyrites also exists in many parts of the colony. Chrome iron ore exists in abundance at Tamworth and on the Gwydir River and its tributaries, also at Gordon Brook, Armidale, &c. At Tamworth there is a vein of chrome iron 40 feet thick, specimens of which showed upon analysis 64·72 per cent. of chromic oxide and 21·11 per cent. of ferrous oxide. Professor Liversidge states that this vein could be easily and profitably worked. The chief obstacle, however, to the working of chrome iron ore, or indeed of any other kind of ore in the colony, is the high cost of labour. Rich seams of magnetic iron ore are found at the ironstone mountain, Port Stephens, eighty miles north-east of Sydney.

Mr. J. S. Mitchell states that coal can now be obtained at the mines at under four shillings per ton, and that it will be possible to manufacture iron at a profit in the colony.*

Iron Ore in New Caledonia.—According to a report recently issued by the French Colonial Office, iron ore, which is most abundant in New Caledonia, accompanies nickel, chromium, and cobalt, and is found in analogous geological conditions, but in larger quantity. According to the testimony of competent men who have had occasion to visit the best ironfields of Europe, nowhere has so great an abundance of iron ore been met with as in New Caledonia. There the

* *The Colliery Guardian*, vol. lxi. p. 502.

ore is not in lodes or in beds; it is in masses. At a large number of points, large masses of ore are encountered, giving on analysis 70 per cent. of ferric oxide, and containing from 2 to 5 per cent. of oxide of chromium. In the Australian colonies which possess iron ore and coal, numerous unsuccessful attempts have been made to produce iron to compete with that of England and America, which is sent to Australia at very low rates as ballast for vessels laden with wood. The presence of 2 to 5 per cent. of oxide of chromium has been formerly noted in New Caledonian ore.*

Goethite from Nova Scotia.—According to Mr. B. J. Harrington,† goethite occurs with red hæmatite, limonite, pyrolusite, calcite, and barytes in veins in the Lower Carboniferous limestone at Clifton, Nova Scotia. It forms for the most part velvety crusts on limonite and calcite. It is, however, occasionally met with in the form of acicular crystals arranged radially. On analysis it yielded the following results:—

Ferric oxide.	Manganic oxide.	Water.	Silica.
88·92	0·14	10·20	0·32

Its specific gravity is 4·217, and its hardness is 5.

A New Minnesota Iron Ore Field.—Rapid progress has been made in opening up iron ore mines in the neighbourhood of Grand Rapids, Minnesota, about 75 miles from Duluth. The new range is known as the Western Mesabi. Captain E. W. Griffin ‡ states, however, that it is rather a continuation of the Vermilion than of the Mesabi. The ore is of a granular character, and when blasted breaks into small pieces. It is more readily reducible than is Chandler ore, and contains only 0·0012 per cent. of phosphorus. One vein of this ore which is now being worked averages 200 feet in width for a distance of from one-half to three-quarters of a mile; it then narrows, but afterwards widens out to 180 feet again. A railway is in course of construction which will open up this district.

Siderite Basins of the Hudson River Epoch.—A recent study by Mr. J. P. Kimball § of the iron ore bodies in course of systematic development at Burden, Columbia County, New York, affords a number

* *The Colliery Guardian*, vol. lxi. p. 714.

† *Jahrbuch für Mineralogie*, 1891, No. I. pp. 241–242; *Canadian Records of Science*, vol. iv. pp. 93–99.

‡ *Iron Age*, vol. xlvii. p. 276.

§ *American Journal of Science*, vol. xl. pp. 155–160.

of interesting facts not unimportant in their bearing on the still rather obscure structural geology of the western margin of the Taconic area extending to the Hudson River, and indeed on the geology of the whole Taconic belt.

The ore basins, four in number, constitute a chain, with their longer axes parallel to the trend of the Taconic and Catskill ranges. The strata of the district are probably all of the Hudson River epoch, and are little altered by metamorphism, though on the western border of the Taconic area. The ore basins themselves are not without remarkable characteristics. They may be described as a series of beds of clay-ironstone intercalated with mechanical sediments, all more or less calcareous as well as ferruginous. While in the southern portion of the second basin well under cover, the iron ore has been metamorphosed into subcrystalline spathic siderite, on the other hand, weathering decomposition has wrought the partial alteration of all the exposed parts of the beds into limonite. Analyses of ores of both types, after calcination, gave the following results :—

	FeO.	Fe_2O_3	MgO.	Al_2O_3	CaO.	P_2O_5.	SiO_2.	MnO.	S.	Total.
I.	2·78	68·23	7·07	2·27	3·36	0·06	11·65	2·92	0·62	98·96
II.	...	65·73	5·72	3·01	4·35	0·32	17·18	2·66	0·78	99·75

I. Spathic siderite; II. ironstone. The low proportion of alumina in contrast with the large proportion of magnesia will not fail to be noticed. This peculiarity may be explained by the detrital derivation of the earthy admixtures from basic rocks, notably hornblendic, as prevailing in the Archæan highlands.

This remarkable series of ore basins seem to owe their origin to depressions on an in-shore mud bottom fed by waters from decomposing basic rocks. The theory of the formation of argillaceous iron ores through saturation of sedimentary rocks with ferrous bi-carbonate fails to satisfactorily account for its formation on a large scale under conditions distinctly pointing to submergence.

Colorado Iron and Manganese Ores.—Mr. J. W. Nesmith,* in advocating the establishment of ironworks in Colorado, gives the following assay results of Colorado iron ores :—

Fe.	P.	S.
49·71–66·42	0·039–0·044	Very low.

A manganese ore from Colorado showed—

Mn.	Fe.	CaO.	MgO.	P.	S.
13·65	34·57	24·74	7·63	nil	nil

* *Iron Age*, vol. xlvii. p. 1077.

Iron Ore in Montana.—Mr. F. F. Chisolm * gives a description of the iron ore deposits of North-Central Montana, as yet undeveloped. Close to the Great Falls is a deposit of bog iron ore containing—

Silica.	Ferric oxide.	Lime.	Manganese.	Sulphur.	Water.
3·04	79·06	0·56	0·30	0·09	17·00

Little development has yet been made of this deposit.

The whole of the Sand Coulee and Belt Creek coalfield is underlain by a bed of iron carbonate, 3 to 6 feet in thickness, yielding on analysis the following results:—

Silica.	Ferric oxide.	Iron carbonate.	Calcium carbonate.	Phosphorus.
12·07	13·00	66·00	4·08	0·04

This ore in its turn is underlain by a very pure limestone.

A New Iron Ore District.—A new line of railway between Cincinnati, Ohio, and Norfolk, Virginia, will pass through a district rich in iron ore, and hitherto void of railway communication. Thus a large deposit of ore is known to exist in the neighbourhood of Watanga in Mitchell County. The ore occurring is the Cranberry magnetite, a massive and generally granular ore. The length of the known outcrop is about 1500 feet. A large number of other ore deposits exist at various places adjacent to the new line.†

Iron Ore in German South-West Africa.—The mineral discoveries hitherto made in that portion of South-West Africa which is now under German protection include both red hæmatite and magnetite. Although very widely distributed throughout this region, neither mineral appears to have been met with in workable quantities.‡

Stanniferous Magnetite.—Professor F. von Sandberger § describes a specimen of magnetite from an abandoned tin mine near Hirschberg on the Saale. This mineral contains ferrous oxide, manganous oxide and magnesia, as well as ferric oxide and tin. The author has not yet determined whether the tin is present as SnO or as Sn_2O_3. In either case, however, there is an interesting analogy to the stanniferous zinc blende recently discovered. It is probable that tin is of frequent occurrence in magnetite, although it has not hitherto been detected.

* *Mineral Resources of the United States*, Washington, 1890, pp. 34-35.

† *Iron Age*, vol. xlvi. p. 739.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 202.

§ *Jahrbuch für Mineralogie*, 1890, No. II. pp. 269-270.

Natural Ferric Sulphates from Chili.—Mr. F. A. Genth and Mr. S. L. Penfield * describe some excellent specimens of the ferric sulphates from Mina de la Compania, near Sierra Gorda, in the province of Tocapilla.

1. *Amarantite.*—The crystallisation is triclinic; colour, brownish-red; hardness, 2·5; sp. gr., 2·286. Analysis (No. I.) gives the formula $Fe_2S_2O_9 + 7H_2O$.

2. *Sideronatrite.*—Optical properties indicate orthorhombic symmetry. Hardness, 1·5; sp. gr., 2·355. Analysis (No. II.) gives the formula: $2Na_2SO_4Fe_2S_2O_9 + 7H_2O$.

3. *Ferronatrite.*—No distinct crystals were observed, but the cleavage and the optical properties show that the crystallisation must be hexagonal. Hardness, 2·5; sp. gr., 2·547. Analysis (No. III.) gave results agreeing with the formula $3Na_2SO_4$, $Fe_2S_3O_{12} + 6H_2O$.

	H_2O.	SO_3.	Fe_2O_3.	CaO.	Na_2O.	K_2O.
I.	28·29	35·46	37·46	trace	0·59	0·11
II.	17·07	44·22	21·77	...	16·39	...
III.	11·89	51·30	17·30	0·22	19·95	0·16

4. *Utahite.*—Minute brownish-white scales from the Mimbres mine, Georgetown, New Mexico, gave on analysis results corresponding with the formula Fe_2SO_6.

Under the name of ferronatrite, Mackintosh † described a sulphate of iron and sodium occurring with other iron sulphates in Chili. As the description of this mineral did not accord with that of a similar mineral from Caracoles, Chili, Frenzel suggested for the latter the name of *gordaite.* The mineral ferronatrite was subsequently described by Genth and Penfield, and from this description A. Arzruni and A. Frenzel ‡ conclude that gordaite and ferronatrite are identical. A new analysis gave—

SO_3.	Fe_2O_3.	Na_2O.	H_2O.	Total.
50·85	17·69	20·22	11·90	100·66

Formula: $3Na_2SO_4$, $Fe_2S_3O_{12} + 6H_2O$.

In a specimen of crystallised iron sulphates from Sierra Gorda, in Chili, L. Darapsky § thought at first that he detected the mineral described by Frenzel as hohmannite. Closer investigation proved,

* *American Journal of Science*, vol. xl. pp. 199–207.
† *Journal of the Iron and Steel Institute*, 1890, No. I. p. 199.
‡ *Zeitschrift für Krystallographie und Mineralogie*, vol. xviii. pp. 595–598.
§ *Jahrbuch für Mineralogie*, 1890, No. II. pp. 267–269.

however, that this was a new ferric sulphate, which the author terms *castanite*. It crystallises in prismatic groups, probably of the monoclinic system. It is of a chestnut-brown colour, with an orange streak and a yellowish orange powder. It is transparent, has a vitreous lustre, a hardness of 3, and a sp. gr. of 2·18. It is distinctly attacked by water, and is soluble with difficulty in hydrochloric acid. On analysis it gave the following results:—

SO_3.	Fe_2O_3.	H_2O.	Al_2O_3.	BaO.	Total.
33·80	33·92	30·76	trace	1·15	99·63

Its formula is Fe_2O_3, $2SO_3$, $8H_2O$. Other known natural ferric sulphates are—

Amarantite	Fe_2O_3, $2SO_3$, $7H_2O$.
Hohmannite	$2Fe_2O_3$, $3SO_3$, $13H_2O$.
Paposite	$2Fe_2O_3$, $3SO_3$, $10H_2O$.

Recent Researches on Meteorites.—Dr. E. Prziwoznik * gives the following analyses of meteoric iron:—

	a.	*b.*
Carbon, combined	4·85	4·85
Iron	90·80	91·70
Nickel	3·24	3·80
Cobalt	0·29	0·70
Copper	trace	...
Phosphorus	0·71	0·59
Sulphur	0·02	...

The iron was obtained from Szlanicza, at the foot of the Magura, in Arva County, Hungary. The analyses show the specimens analysed contained carbon only in the combined state.

An analysis of the meteorite from Hainholz, near Paderborn, gave the following results:—

Silica	36·50
Alumina	7·61
Lime	5·50
Magnesia	12·11
Ferric oxide	32·79
Cobalt oxide	0·34
Nickel oxide	2·23
Phosphoric anhydride	1·16
Water	1·76
Total	100·00

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxviii. p. 399.

In an investigation of the meteoric iron from Magura, Arva County, Hungary, E. Weinschenk * succeeded in isolating the following constituents:—

1. Tin-white regular crystals, hitherto regarded as schreibersite. These appear to have a cleavage perpendicular to the longitudinal axis; they are strongly magnetic, very brittle, and soluble in hydrochloric acid and copper ammonium chloride, with separation of carbon. The hardness is 5½ to 6, and the specific gravity 6·977. Analysis (No. I.) gave, after subtraction of schreibersite, results corresponding with the formula $C(FeNiCo)_3$. For this new mineral the author proposes the name of *cohenite.*

2. Thin, silver-white, strongly magnetic lamellæ, which are but slowly soluble in hydrochloric acid, and which may represent Reichenbach's *tænite.* The composition (Analysis II.) is in accord with the formula $Fe_5(NiCo)_2$.

3. Fragments of various shapes, which form the principal mass of the iron. They are highly magnetic, sparingly soluble in hydrochloric acid, and give on analysis (No. III.) results corresponding with the formula $Fe_8(NiCo)$. The high percentage of cobalt is noteworthy—

	Fe.	Ni.	Co.	C.	Cu.	Sn.	Schreibersite.	Totals.
I.	89·83	3·08	0·79	6·43	trace	trace	0·65	100·78
II.	71·04	26·64	1·67	0·30	...	...	...	99·65
III.	87·96	9·19	2·60	0·38	...	...	...	100·13

4. Crystals of rhombic and monoclinic augite.

5. Grains of partly isotropic, partly weakly bi-refractive diamond, proved to be harder than ruby, and to burn to carbonic anhydride in a current of oxygen.

Colourless or strongly pleochroic blue grains appear to consist of corundum, whilst small colourless aggregates may be tridymite.

The author compares the varieties of carbon met with in meteoric iron with those in pig iron. The "hardening-carbon" corresponds with the carbon given off in the form of hydrocarbons when the meteoric iron is dissolved in hydrochloric acid; the ordinary carbide carbon corresponds with cohenite; the graphitic temper-carbon with the carbon in the residue when meteoric iron is dissolved; and lastly graphite is met with in both varieties of iron. This perfect analogy leads to the assumption that the conditions under which meteoric iron

* *Jahrbuch für Mineralogie,* 1890, No. II. pp. 57–59.

was formed are comparable to those under which pig iron is produced, and the presence of the diamond indicates that the carbon dissolved or chemically combined in iron can under certain conditions separate out in the allotropic form of the diamond.

From the examination of a considerable number of fragments of the Ochansk meteorite, J. von Siemaschko * concludes that the division of meteorites is not effected instantaneously by explosion, but by the repeated separation of fragments. In this meteorite the brecciated structure is highly developed. The melted iron met with in the outer layer of the meteorite occurs in the form of grains or plates. One of these plates treated with acid did not exhibit Widmanstätten lines. It had the following composition :—

Fe.	Ni.	Co.	P.	S.
79·12	11·38	trace	0·74	8·44

The most noteworthy point about this meteorite is the occurrence of yellow iron-sulphide in pentagonal dodecahedra, as this is the first time that iron pyrites has been observed with certainty in a meteorite.

Mr. G. F. Kunz † has published descriptions of the following five new American meteorites.

1. Meteorites from Brenham Township, Kiowa County, Kansas. Twenty meteorites, weighing altogether 2000 lbs., were found in this district in 1886. The following is an analysis of these meteorites :—

Fe.	Ni.	Co.	Cu.	P.	S.	C.	Si.
88·49	10·35	0·57	0·03	0·14	0·08	trace	trace

The olivine (I.) and the dark outer zone of olivine (II.) gave the following results :—

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	NiO.	CoO.	MnO.	MgO.	S.
I.	40·70	trace	0·18	10·79	0·02	...	0·14	48·02	...
II.	34·14	...	...	23·20	trace	0·03	0·09	40·19	5·42

The sp. gr. of the iron freed from olivine was 7·93, whilst that of the olivine was 3·376. The iron is brilliant white, enclosing the troilite and surrounding the olivine crystals. The outer zone of dark brown olivine is in reality composed of an intimate mixture of troilite and olivine. This group of meteorites is of special interest because of the probable connection with the meteoric iron found in 1883 in the Turner mounds in Ohio.

2. Meteorite from Winnebago County, Iowa. This meteorite was observed to fall on May 2, 1890. It is a typical chrondrite, with a

* *Tschermak's mineralogische Mittheilungen*, vol. xi. pp. 87–90.

† *American Journal of Science*, vol. xl. pp. 312–323.

sp. gr. of 3·638, and is composed approximately of 19·40 per cent. of nickeliferous iron, 6·19 per cent. of troilite, 36·04 per cent. of silicates soluble in hydrochloric acid, and 38·37 per cent. of silicates insoluble in hydrochloric acid. The nickeliferous iron on analysis gave the following results :—

Fe.	Ni.	Co.	P.	Total.
92·65	6·11	0·65	trace	99·41

3. Meteoric stone from Ferguson, Haywood County, North Carolina. This fell on July 18, 1889. Its weight was about 8 oz., and it very closely resembled the meteoric stone from Moca, Transylvania.

4. Meteoric iron from Bridgewater, Burke County, North Carolina. This weighs 30 lbs. and measures 22½ by 15 by 10 centimetres. It belongs to the caillite group, and resembles the Cabin Creek and Glorietta Mountain meteorites in structure. Analysis gave the following results :—

Fe.	Ni.	Co.	P.	Cl.	Total.
88·90	9·94	0·76	0·35	0·02	99·97

Its sp. gr. was 6·617.

5. Meteoric iron from Summit, Blount County, Alabama. This meteorite weighs 2·2 lbs., and measures 5 by 2 by 3 inches. It contains a large quantity of free iron chloride, and showed only a slight trace of the original crust, being almost completely oxidised. On etching with nitric acid, no Widmanstätten figures were developed, but merely a fine marking similar to that of the Linnville meteorite. Analysis gave the following results :—

Fe.	Ni.	Co.	P.	Total.
93·39	5·62	0·58	0·31	99·90

The sp. gr. was found to be 6·949.

Mr. E. E. Howell,* describes two new iron meteorites.

1. Meteorite from Hamilton County, Texas. This was discovered in 1887. It weighed 179 lbs., the two greatest dimensions being 17½ and 13 inches. The Widmanstätten figures are brought out with remarkable rapidity on the application of very dilute acid. The amount of troilite found in cutting the iron is not great, and seems to be distributed in thin narrow plates, no nodules having been met with. On analysis, the iron yielded the following results :—

Fe.	Ni.	Co.	Cu.	P.	S.	C.	Total.
86·54	12·77	0·63	0·02	0·16	0·03	0·11	100·26

Its sp. gr. is 7·95.

* *American Journal of Science*, vol. xl. pp. 223-226.

2. Meteorite from Puquois, Chili. This is said to have been found in 1884. It weighed 14 lbs. 7½ oz., the two largest diameters being 10 and 5½ inches. The surface of the iron is unusually smooth, only a few shallow pittings being visible. The etched sections show that the mass has been subjected to fracture and dislocation, resulting in an undoubted faulting of the Widmanstätten figures and of the troilite. In all probability these are the first faults observed in an iron meteorite. They are clearly not produced by the impact of the fall upon the earth, but are a part of the meteorite's earlier history. On analysis, the iron yielded the following results :—

Fe.	Ni.	Co.	Cu.	P.	S.	C.	Total.
88·67	9·83	0·71	0·04	0·17	0·09	0·04	99·55

Its sp. gr. is 7·93.

Mr. F. P. Venable * describes the following two new American meteoric irons :—

1. A mass is reported to have fallen in 1846 at Deep Springs Farm, in Rockingham County, North Carolina. It is now in the possession of the State Museum. The weight of the mass was 11·5 kilogrammes. It had the shape of a rhomboid, and was coated with oxidation products. giving it a dull reddish colour. The surface is irregularly pitted. On being polished and etched, it faintly exhibited Widmanstätten figures. It belongs to the class of sweating meteorites, beads of ferric chloride appearing on the surface. The analysis gave—

Fe.	P.	SiO_2.	Cl.	Ni.	Co.	Total.
87·01	0·04	0·53	0·39	11·69	0·79	100·45

2. A meteoric iron was found in 1889 in Henry Co., Virginia. It weighed 1·7 kilogramme, and the detached pieces, mainly crust, weighed 0·22 kilogramme. The iron contains a considerable amount of ferric chloride, and rapidly crumbles. On polishing one of the sides, the Widmanstätten figures came out plainly, no etching being necessary. The analysis gave the following results :—

Fe.	Cl.	SiO_2.	P.	Co.	Ni.	Total.
90·54	0·35	0·04	0·13	0·94	7·70	99·70

Mr. O. W. Huntington † describes a meteoric iron from North Dakota, a specimen of special interest. It was found in 1885 during the construction of a branch of the Northern Pacific Railroad, about twenty miles south-east of Jamestown, Stutsman Co., North Dakota. It weighs 4015 grammes, and is of peculiar shape and appearance, in

* *American Journal of Science*, vol. xl. pp. 161–163.

† *Proceedings of the American Academy of Sciences*, vol. xxv. pp. 229–232.

that it appears to be a thick scale blown off from the spherical surface of a large body. The iron is so malleable that it can be rolled out into thin ribbon in the cold, and it breaks like a soft semi-solid material. The extreme malleability and peculiar fracture separate this iron from all others hitherto described. The concave side of the specimen is characterised by a vesicular structure not unlike that of certain furnace specimens. These cavities, which are distributed with some regularity in three more or less parallel zones across the shorter dimension of the surface, appear to have no connection with the pittings on the surface, and are different from anything hitherto observed in other meteoric irons. They suggest an evolution of gas from the material in process of cooling. This may have been the cause of the splitting off of the specimen from the original mass. A preliminary analysis of the iron gave the following results :—

Fe.	Ni.	P.	Cu.	Total.
90·24	9·75	0·05	trace	100·04

No trace of sulphur was detected. A point of interest in this iron is that it was found at the bottom of a slanting hole, rendering it probable that it belonged to a comparatively recent fall.

According to Mr. A. R. Ledoux,* a meteorite, weighing 13½ kilogrammes, was found in December 1887 near Pipe Creek, thirty-five miles south-west of San Antonio, Texas. Analysis yielded—

	Per Cent.
Magnetic portion	30·89
Non-magnetic portion	69·11

The magnetic portion gave—

Fe.	Ni.	Total.
90·94	9·00	99·94

and the non-magnetic portion, silicates and iron sulphide, gave—

SiO_2.	S.	CaO.	MgO.	P.	Fe_2O_3.
35·61	3·45	2·25	15·09	0·25	12·15

The analysis of a second fragment found at Waldon Ridge, Cumberland Gap, Tennessee, gave 93·86 per cent. of iron and 6·01 per cent. of nickel.

Formation of Manganese Deposits.—A meeting of the Royal Society of Edinburgh † was taken up by the consideration of the formation of manganese deposits in the sea, and several papers bearing

* *Transactions of the New York Academy of Science*, vol. viii. pp. 186–187.

† January 9, 1891; *Nature*, vol. xliii. pp. 287–288.

on the question were read. Dr. J. Murray believes that the manganese is deposited in round nodules from solution by way of the carbonates. The nodules are found in great abundance in deep waters, where there is a minimum of organic life. Mr. R. Irvine and Dr. J. Gibson find, by experiment, that manganous sulphide is dissolved and decomposed by sea-water, which contains carbonic acid. Mr. J. Y. Buchanan gives the analyses and characteristics of a number of nodules. A discussion ensued on these and on previous papers.

Manganese Ore in Russia.—N. Kozoffski * describes the manganese ore deposits of Transcaucasia. The pyrolusite in the vicinity of the station at Adschamet occurs in a calcareous sandstone. The following are analyses of the ore :—

	I.	II.	III.
Water	0·61	1·04	5·78
Insoluble in acids	0·47	5·04	8·47
Silica	0·89	4·36	7·38
Phosphoric anhydride	1·12	1·02	1·16
Manganese	57·02	55·00	15·50

In another communication, N. Kozoffski † describes the manganese ore deposits of the Ekaterinoslav district. The ore was discovered in 1883, and from 1886 to 1888 about 10,000 tons were raised. The ore, pyrolusite, occurs in a manganiferous clay. Analysis yielded the following results :—

	IV.	V.
Manganese dioxide	85·07	81·03
Phosphorus	trace	0·36
Ferric oxide	1·23	1·90
Silica	8·10	9·33
Copper oxide	1·37	1·95
Sulphur	0·08	0·07
Magnesia	1·08	0·85
Totals	96·93	95·49

Manganese Ore from Virginia.—Mr. J. L. Jarman ‡ gives the

* *Gornyj Journal*, vol. iv. pp. 1-29.
† *Gornozavodskij Zistok*, vol. i. pp. 269-271.
‡ *Zeitschrift für Krystallographie*, vol. xviii. p. 544.

following results of an analysis of pyrolusite from the Crinon mine, Augusta County, Virginia:—

MnO.	O.	Fe_2O_3.	CaO.	NiO.	CoO.	K_2O.	Na_2O.	H_2O.	Insoluble.	Total.
78·77	17·61	0·62	0·09	0·22	0·27	0·18	0·23	2·09	0·29	100·37

The mineral examined consisted of a mass of fibrous crystals, having a hardness of 2·7 and a specific gravity of 4·69.

II.—*IRON ORE MINING.*

Poetsch's Method of Shaft Sinking.—According to R. Wabner,* on February 28, 1891, the sinking of a shaft at Georgenberg, Upper Silesia, by the Poetsch method of freezing, was successfully completed. Altogether, the sinking, with the installation of the requisite machinery, the boring operations, the production of the frozen wall round the shaft, the timbering, and the removal of the machinery, occupied nine months.

The shaft, which is intended to open up the iron ore deposits of the district, is 15 feet in length and 10 feet in breadth, and was carried down to a depth of 78 feet through quicksand overlying the limestone. Previous attempts had been made to sink the shaft by spilling, but it was found impossible to sink deeper than 45 feet. The new shaft is very strongly timbered, and is lined with clay, and it is now intended to continue the sinking to a depth of 190 feet in the limestone, so as to give easy access to the bed of brown hæmatite.

The Prevention of Over-Winding.—At mines in Saxony the danger due to over-winding has been diminished by causing the guide-rods to approach one another gradually above the shaft, until they are nearer together than the width of the over-wound cage, which would then jam.†

Action of Preservative Agents on Mine Timber.—At Saint Eloy, in Auvergne,‡ experiments on the action of antiseptic agents on the duration of timber underground have been in progress since 1879. The preservative action of the different substances employed is shown

* *Berg- und Hüttenmännische Zeitung*, vol. l. p. 98.

† *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890. p. 109.

‡ *Comptes Rendus de la Société de l'Industrie Minérale*, 1890, p. 223; *Minutes of Proceedings of the Institution of Civil Engineers*, vol. civ. p. 394.

in the following table, which represents the increase in the duration of the protected specimens in terms of that of the unprotected ones, the latter being taken as unity :—

	Oak.	Fir.	Pine.	Beech.	Birch.	Poplar.
Tar	28·7	263·5	87·5	105·4	26·2	150·5
Zinc chloride . .	10·5	50·0	26·3	18·6	52·5	34·7
Oil paint	6·1	31·7	54·5	25·0	12·1	2·5
Copper sulphate . .	42·1	12·0	8·0	1·8	2·5	15·5
Ferrous sulphate . .	18·0	12·1	4·2	4·7	3·5	2·9
Creasote . . .	1·7	2·5	4·4	0·6	3·3	1·3

Boring with Power Drills.—At the Bautenberg iron mine in the Burbach district, a level 8 feet 3 inches in height and 5 feet in width has been driven by means of the Jäger rock drill. The rock traversed consisted of hard sandstone and slate. There were three shifts during the twenty-four hours, and in each shift one drill was in operation, worked by two men. In four months of twenty-five working-days each, 525 feet were driven, 1·7 foot being driven per eight-hour shift. The cost of wages in driving one metre, including the setting up of the machine and the removal of the rock, amounted to 45s. To this must be added 10s. for compressed air, so that each metre cost altogether 55s. If hand-boring had been used, the cost would have been 70s.*

Drills of the Elliot pattern have been experimented with at the Nordstern and Anna mines, Prussia. Good results were obtained in drilling both in coal and in rock of medium hardness. In slate of medium hardness at the Nordstern mine, a hole 52 inches in depth was bored in forty minutes, including the time required to place the drill in position. In the Mansfeld district the Franke drill has given satisfaction.

Other drills which have given satisfaction are those of Fröhlich and the combined Fröhlich-Jäger, these latter being largely employed at the Duisburg mine, where vughs are of constant occurrence, the Jäger brake proving of great use in preventing the cylinder-head being broken by the piston of the drill when such a vugh is met with in driving. The total cost of the drilling plant used at this mine, including compressor plant, turbine, six drills, &c., was £1367. A table is published giving complete details as to the cost of driving a level with these drills and in stopping. The results were greatly in favour of the use of these drills as compared with hand labour.

* *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 371.

At some of the mines a small pipe with the end more or less bent is used with advantage in supplying a current of water to keep the bore-hole clear during the drilling.*

Trials of Rock Drills.—The recent trials of rock drills made at the Exhibition of Mining and Metallurgy at the Crystal Palace are described by Mr. E. H. Carbutt and Mr. H. Davey.† The drills exhibited were all of the striking or percussive kind, and may be divided broadly into three classes—(1) drills in which the valve is worked by air-pressure; (2) drills having the valve worked through mechanical connections by tappets or cams; (3) valveless drills, in which the main piston itself performs the office of valve. In the first of these classes, the piston performs the function of a valve for reversing the actual valve, while the latter in its turn causes the motion of the piston to be reversed. In the second class, the motion of the piston is employed to reverse the valve by knocking it over the ports.

Some hand-power drills were also exhibited. The drills which entered the competition were M'Culloch's "Rio Tinto" drill, Stephen's "Climax" drill, Bickle drill, Ingersoll-Mayne drill, Daw drill, Coles' drill, Hathorn's "Eclipse" drill, Ingersoll hand-power drill, and the Bromfield-Ingersoll hand-power drill. A description of each of these drills and of the air meter used is given. The trials were made on a granite block bedded on concrete, and, as a comparison, a hole was bored by three men, one holding the drill and two strikers. Air was supplied at 60 lbs. to 70 lbs. per square inch, and the pressure recorded every half-minute. The judges stated that the drills which did the greatest quantity of work in the given time did also the greatest quantity of work per cubic foot of air used, as far as could be ascertained.

The authors think that from the actual results of the work done by the rock-drilling machines which were tried, it is difficult to form any broad and general conclusions as to the efficiency of the different drills, as this may be connected with variations in the principles and details of the valve mechanism employed. What really does appear is that the important points are purely of a practical nature, and the following may be profitably discussed:—mechanical details, certainty of action, weight of mechanism in relation to durability and portability. It did not appear at the trials that there was any practical difference in the

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxviii. pp. 260–264.

† *Institution of Mechanical Engineers, Proceedings*, 1891, pp. 141–188, eleven plates.

certainty of action between the valves moved by air and those worked by tappet.

As regards the weight, the heavier machines did the best work; and though portability is often a great object, yet strength of parts is still more important.

From the particulars given of the work done by the hand-power machines, it does not appear that these are equal in efficiency to the hand-hammer in drilling vertical holes. The first machine with two men drilled a 1¼-inch hole 12·37 inches deep, having a capacity of 16·69 cubic inches, in 17 minutes; whilst three men by hand, two striking and one holding the chisel, drilled a somewhat larger hole 22 inches deep, having a capacity of 27·64 cubic inches, in 18½ minutes. In this comparison no allowance is made for the labour of moving and fixing the machine.

Tabulated statements of the performances are appended, to show the dimension of the drills, the size of the holes, the amount of air used, and other particulars, and the rules for the competition are also given.

Driving Levels in Hard Rock.—M. Lombard,* in a paper read before the *Société de l'Industrie Minérale*, describes a method for driving levels, which in certain circumstances may admit of as rapid driving by hand drills, as by drills worked by compressed air. The author's method involves—(1) the correct use of an adequate quantity of explosive; (2) the placing of the bore-holes in a regular manner, all being made parallel with the axis of the level; (3) a depth for the bore-holes of from 29·2 to 39·3 inches; (4) the use of hand drills and the employment of workmen sufficiently skilled in their use to drill and fire two shots in each shift; (5) the simultaneous firing of all the shots, and the rapid clearing away of the debris.

The method was introduced at a number of places, and descriptions are given of its use at Gardanne, Prades, and Bességes. At this latter place the rock through which the level was driven was at first somewhat difficult to drill, and the method was afterwards applied under specially difficult circumstances, the rock being an exceedingly hard sandstone.

The results of these trials are given at some length, and it is shown that in the majority of cases the method of working, which the author describes, possesses great advantage over ordinary hand-drilling.

* *Comptes Rendus Mensuels*, 1890, p. 55.

The Use of Hand Drills.—Hand drills have replaced air drills in drilling holes in sandstone in the Oelsnitz district, Saxony, but they did not prove successful in conglomerate, as the drills could not attack the large quartz masses met with.*

Simultaneous Shot-Firing.—At the Merkur mine, near Ems, in all cases where more than five shots have to be fired, the miner is required to bind the fuses together at their ends into one or two bundles according to their number, and then to fire the bundle. By varying the lengths of the several fuses the shots may be caused to follow one another at any desired interval, the miner being thus enabled to count the separate explosions and to ascertain whether a shot has missed fire.†

Transmission of Power.—At Hjulsjö, in the Nora mining district of Sweden, rope transmission of 25 horse-power exists for a distance of nearly a mile and a half. The first cost, in addition to that of the hydraulic machinery, was £350. Electric transmission under similar conditions would have cost some 40 per cent. more, but once erected, would have been considerably cheaper and easier to run. The running ropes require continuous looking after, but the fixed electric conductors require little attention. Electricity possesses, too, marked advantage over compressed air as a carrier of power.‡

Mining of Manganiferous Iron Ore near Giessen.—According to J. Uhl,§ in the Lindener Mark, near Giessen, the ore was formerly worked by washing out the argillaceous portion, consisting of highly manganiferous brown iron ore, use being made solely of the admixed solid fragments of brown iron ore. The residue remaining in the settling ponds is now of considerable value, and is consequently worked. It consists of a very fine granular mass, containing 27 per cent. of manganese dioxide, the remainder being lime and clay. The mass is found to exhibit the peculiarity of basalt on cooling, in that it forms on drying vertical columns about 3 feet in height and 1½ foot in thickness, with a more or less distinct lamination at right angles to the vertical axis, due probably to the original stratification of the entire mass.

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 118.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxviii. p. 264.

‡ *Ingeniörs-Föreningens Förhandlingar*, 1890, p. 32.

§ *Bericht der Oberhessischen Gesellschaft für Naturkunde*, vol. xxvii. pp. 114–134.

Shipping Iron Ore.—The ore dock of the Duluth South Shore and Atlantic Railway Company at Marquette, Michigan, is described with the aid of a large number of dimensioned sketches and illustrations in the *Engineering and Mining Journal.** In the three already existing docks, there was room for 31,000 tons of soft ore. The new dock is 530 feet long, and holds 29,000 tons of soft ore. The pockets have been so designed that no waste space is left, and hinged shoots with counterbalances are used. The dimensions of the various parts are fully given.

III.—*MECHANICAL PREPARATION.*

Iron Ore Washing in Upper Hessen.—At the village of Niederohmen, near the Vogelsberg, in Upper Hessen, a very complete ore-dressing plant has been erected. It comprises a 70 horsepower steam-engine, and two washing drums with accessories, and enables a daily production of 15 double waggons to be attained. The basaltic iron ore washed contains 46 to 48 per cent. of iron.†

Magnetic Concentration of Iron Ore.—The progress in magnetic concentration of iron ores is discussed by Mr. J. Birkinbine,‡ with special reference to the contributions to this subject by Messrs. Fowler, M'Dowell, Clemens Jones, and Ball.§ Concentration at the Tilly Foster Mine is carried on so as to yield a comparatively lean product on account of its value as a flux, but much of the iron is lost in the tailings. This loss is also large at the Michigamme Mine, and at the same time much of the phosphorus is removed from the concentrates. The author gives calculations to show the weight of crude material required and the loss sustained to obtain a ton of concentrates. Several plants for magnetic concentration are already at work, or nearly ready, in the United States, and others are in course of construction. At the present time there is much objection to the use of concentrated iron ores in the furnace, on account of supposed difficulties in working, but fine ore is often used with success. The value of concentration should not be underrated, as phosphorus can generally be eliminated if the ore is crushed fine enough, and the

* Vol. li. pp. 62, 88, 116. † *Glückauf*, 1891, No. VI.

‡ *Transactions of the American Institute of Mining Engineers*, vol. xix. (advance proof). § *Journal of the Iron and Steel Institute*, 1891, No. I. pp. 671–676.

expense depends on the fineness. Sulphur, if it occurs as pyrites, can be eliminated more easily than by roasting. Titaniferous ores can also be treated, although recently not much attention has been paid to them.

As far as the enrichment of lean magnetite by crushing, sizing, and separating magnetic from non-magnetic material is concerned, it may fairly be pronounced a commercial success. The cost of the process in case of phosphatic ores depends on the degree of comminution to which the ore must be reduced to permit a separation. It varies greatly for different ores, but from the data given by Messrs. M'Dowell and Fowler, and after allowing for the cost of handling, and for royalties, &c., there are few places where the expense of crushing, sizing, and separating one ton of crude ore should exceed two shillings, and in a majority of cases it should be less than this.

For finding the number of tons of crude ore to produce a ton of concentrates, the following rule may be adopted :—The percentage of iron in concentrates, minus the percentage in tailings, when divided by the percentage in the crude ore, minus the percentage in tailings, gives the required amount.

At the magnetic concentrating plant of the Croton Iron Mines, near Brewsters, the ore is roasted in three Davis-Colby kilns, modified so as to burn oil as a fuel.* The ore is crushed hot in a Sturtevant mill, screened, and passed through six Hoffmann concentrators. The tailings are treated on another machine. One of the roasters will be equipped at an early date with a rotary conveyor, to deliver the roasted ore into the trough elevator, which takes the ore to the Sturtevant mill, situated on the top floor of the building. The concentrator plant is producing about 200 tons of concentrates in twenty hours, the greater part being used by furnaces in the Lehigh and Schuylkill Valleys in making foundry iron. Some low phosphorus concentrates are also being produced. Plans are under consideration for the construction of a large mill capable of handling from 2500 to 3000 tons of rock per day.

Magnetic Separation of Iron from other Ores.—According to G. Prus,† magnetic separation is the only method which can be profitably employed to separate iron from other ores in many cases, unless hand-picking is available. Mechanical separation is often impossible, as the specific gravity of the different materials is nearly

* *Iron Age*, vol. xlvii. p. 787.

† *Le Génie Civil*, vol. xvii. p. 337, with plate.

identical. By a Siemens machine quantities of zinc ore up to a ton an hour are treated, and 60 to 70 per cent. of the iron is taken out at the Mercadal Mines, Spain. Another type of machine, the Kessler, is also used. Particulars are given of the machines and of the power employed. Drawings are also given of the vial separator, which is described in detail.

The author enumerates the appliances required for such an installation, and then proceeds to discuss the results which are obtainable, reference being more particularly made to the separation of the oxides of iron and zinc. He shows that as the percentage of iron increases in the material under treatment, the results become more and more satisfactory. It is necessary to convert the ferric oxide of the ore into magnetic oxide before the separation, and this is done by mixing the material to be subjected to calcination with from 1 to 5 per cent. of fine coal.

REFRACTORY MATERIALS.

Fire-clay from Bohemia.—According to Heinecke,* fire-clay from Oberbriz in Bohemia contains:—

	Plastic Clay.	Shale.
Silica	50·76	47·46
Alumina	30·16	36·35
Ferric oxide	0·47	1·52
Lime	trace	...
Magnesia	0·59	...
Alkalies	1·83	1·21
Loss on ignition	16·37	13·65

The clay is of an extremely refractory nature.

Russian Fire-clay.—Glasenapp † gives the following analyses of fire-clay from the coal and lignite measures of the Ural (I. II. III.), and from the Mountain limestone of Moscow (IV. V.).

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Alkalies.	Ignition.
I.	47·20	34·05	4·65	0·96	0·70	0·35	14·31
II.	53·93	25·76	4·88	0·77	0·52	0·26	14·31
III.	48·93	36·56	1·68	0·66	0·56	0·19	11·65
IV.	65·13	22·52	2·20	0·48	0·90	...	7·90
V.	70·33	9·73	2·00	1·20	0·48	...	6·06
	78·63	16·56	2·86	2·53	1·32	...	8·03

Magnesite in the Ural.—Kleye ‡ has discovered an extensive deposit of magnesite at Werchnenval in the government of Orenburg. The mineral contains but traces of calcium carbonate, ferric oxide, and silica. No discovery of magnesite in the Ural has hitherto been recorded.

Bauxite from Arkansas.—Mr. J. C. Branner § announces the discovery of a large deposit of bauxite in Arkansas, covering an area of some 640 acres, in the counties of Saline and Pulaski. It occurs in

* *Thonindustrie Zeitung*, 1891, No. I.
† *Ziegel- und Töpf-Zeitung*, vol. xxi. p. 916; vol. xxii. p. 22.
‡ *Berg- und Huttenmännische Zeitung*, vol. l. p. 179.
§ *American Manufacturer*, vol. xlviii. p. 119.

irregular beds, whose thickness and extent have not yet been determined. It is found in Tertiary areas in the neighbourhood of granite. Analyses of several samples gave results as follows :—

Silica	10·13	11·48	5·11	4·89	3·34
Alumina	55·59	37·02	55·89	46·44	58·60
Iron oxide	6·08	1·83	19·45	22·15	9·11
Water	28·90	28·63	17·39	26·68	28·63

Other reports state that extensive deposits of bauxite have been found in Arkansas in irregular patches.* As this mineral has, with the exception of a single bed in Georgia, never before been found in the United States, the discovery is likely to prove a valuable one.

Bauxite from Austria.—Dr. E. Prziwoznik † gives the following analyses of bauxite :—

	a.	*b.*	*c.*	*d.*	*e.*
Alumina	51·47	67·64	52·63	53·31	51·36
Ferric oxide	19·07	0·72	26·28	13·43	19·29
Manganese oxide	1·81	...	trace	trace	trace
Lime	trace	0·10	0·30	trace	0·15
Magnesia	0·37	0·14	0·28	0·18	0·18
Silica	2·70	5·90	5·40	4·35	14·40
Titanic anhydride	2·10	1·53	2·65	1·95	2·05
Sulphuric anhydride	0·31	0·34	0·13	0·17	0·24
Phosphoric anhydride	0·96	0·72	0·69	0·50	0·38
Water	21·20	23·10	11·45	26·35	12·20
Totals	99·99	100·19	99·81	100·24	100·25

a. Brown variety from Savitza, in Carinthia; *b.* grey variety from Althammer, Wochein; *c.* brown variety from the same place; *d.* marbled variety also from Althammer; and *e.* variety mixed with clay from Kreschdorf, Carinthia.

Chrome Iron Ore Linings.—Dr. Lundström ‡ reports that chrome iron ore has been found eminently suitable for lining the sides of open-hearth furnaces. As a lining for the bed, it has been found less satisfactory. As is well known, chrome iron ore consists of chromic oxide and ferrous oxide. It may thus be regarded as a magnetite in which the ferric oxide is replaced by chromic oxide. In Russian and

* *Bradstreet's*, March 7, 1891; *Board of Trade Journal*, vol. x. p. 446.

† *Berg- und Hüttenmännische Jahrbuch der k.k. Bergakademien*, vol. xxxviii. pp. 415–416.

‡ *Wermländska Annaler; Berg- und Hüttenmännisches Zeitung*, vol. xlix. p. 316. Compare *Journal of the Iron and Steel Institute*, 1890, No. I. p. 217.

Norwegian chrome ore, which has hitherto been employed, the gangue consists of serpentine. It is an extremely refractory material, being more difficult to melt than platinum. With fluxes, such as potash under access of air, it becomes fusible, forming potassium chromate.

According to Stahl, furnace linings of good quality have recently been made of chrome ore with thin layers of dolomite. The slag is thus prevented from taking up silica, and the run of the furnace is accelerated. With 50 per cent. of chromic oxide, this material costs in Stockholm £5, 12s. 6d. per ton.

In the vicinity of Frankenstein, A. Reitsch * discovered veins of chrome ore traversing the serpentine, but attempts to work the deposits have not proved remunerative. A fresh discovery on the Zobten Mountain appears to be more promising. The ore bed has a thickness of 7 yards, and this appears to increase with the depth. The ore is a magnesia-bearing chromite, containing 35 to 42 per cent. of chromic oxide.

Brickmaking Machine.—A machine for this purpose, which is illustrated in the *Iron Age*,† is especially designed for working stiff clay as it comes from the bank. The clay may be delivered by a carrier discharging it into a very heavy cast iron cylinder surrounding the vertical shaft which carries the arms that pug the clay, and also gives motion to all other working parts. The pugging cylinder varies in diameter, the larger diameter being beneath where the final pugging is effected and the clay delivered to the moulds. The machine is practically double, having on each side a mould, a pressing plunger and a discharging plunger. While the brick is being pressed on one side a finished brick is being discharged on the other, giving two complete bricks at each revolution. Thus, at the speed of 17 revolutions per minute the product per hour would be 2040 bricks, which are claimed to be so perfect and so dense that no pallets are required, but the brick can be taken directly to the dryer.

The brick is pressed on edge and delivered to travelling belts directly beneath the moulds. The brick leaves the press with smooth, flat sides, square edges and corners, and requires no trimming, the result being that the brick will lay close and present a smooth and finished appearance. The total weight of the machine is about 11 tons and it requires 20 to 25 horse-power.

* *Thonindustrie Zeitung*, 1890, No. 48.
† Vol. xlvii. p. 3.

FUEL.

CONTENTS.

I.—*CALORIFIC VALUE.*

Calorimetry.—Mr. B. Donkin and Mr. J. Holliday * divide the methods of determining the calorific power of fuel into three classes. First, by calculation from the chemical analysis; second, by combustion on a small scale in some form of calorimeter; and third, by combustion on a large scale under a well-arranged steam-boiler. For the first method a complete analysis is required, and even then the determination is not certain, as authorities are not agreed on the values to be assigned to the various combustible elements. Carbon gives 14,544 British thermal units, hydrogen 62,032, and sulphur 4032 units. Cornût, however, assigns a value of 20,185 to the volatile portion of the carbon. Dulong only considers the available hydrogen after the oxygen is satisfied, and Ser uses the formula 5184 ($\frac{1}{3}$ carbon + 8 hydrogen). Scheurer-Kestner † has compared the results obtained by these and by experimental methods, and shows that sometimes one formula and sometimes another gives results nearest to the experimental figure. A correction has to be made for the vaporisation of water; this may be done by taking the calorific value of hydrogen as 52,357 instead of 62,032.

More exact results may be expected from Scheurer-Kestner's experiments with Berthelot's bomb. In the latest form of this apparatus, a thin glass globe with a stream of oxygen flowing through it is used.

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cii. pp. 292–304.

† *Journal of the Iron and Steel Institute*, 1888, No. II. p. 190.

Several calorimeters have been devised, and for commercial use, that of Lewis Thompson is the most used. Experiments have led the author to believe that 15 instead of 10 per cent. should be allowed for errors. With coals rich in hydrocarbons, this instrument is fairly certain in its working, but coke and anthracite do not behave well in it. For testing the value of this and other calorimeters, a sample of charcoal free from hydrogen, or a coal of known calorific value should be burnt in it. Dr. F. Stohmann and C. von Rechenberg have improved and modified this instrument. They use a combustion tube of platinum and a combustion mixture of oxide of manganese and potassium chlorate. The instrument is carefully jacketted to prevent radiation. The authors, however, conclude that the best calorimeter for ordinary use is that of Professor W. Thomson, in which the diving-bell arrangement is retained, but a stream of oxygen is used instead of potassium chlorate to support combustion. Any coal containing less than 25 per cent. of incombustible matter can be tested in this apparatus, but if the coal is smoky, some difficulty sometimes occurs. Slight modifications have been introduced by one of the authors in the use of a glass vessel and in the arrangement of the parts. The average loss by radiation is 0·02° C. per minute, and the total losses are about 2 to 3 per cent.

Calorimetric results should sometimes be tested on a practical scale under a boiler. In some cases the results come out low, and in others high. Unfortunately no public station for this kind of testing exists in England, but several on the Continent have been working for some years.

M. Scheurer-Kestner * describes some experiments that he has made with the calorimetric bomb of Berthelot.† There are two points in connection with this apparatus. M. Berthelot has introduced a correction for the nitric and sulphuric acids formed during the combustion of the coal, but this error is practically negligible, especially as somewhat similar amounts will be formed during combustion on a practical scale. The second point is, that it is impossible to weigh the ash unless the coal is made into pastilles, as recommended by Berthelot. Experiments with this apparatus always give results from 1 to 3 per cent. below those given by the apparatus of Favre and Silbermann. Several examples of this are given by the author, who concludes that the corrections tend to reduce the number of coals with calorific values greater than those deduced from their composition.

* *Comptes Rendus de l'Académie des Sciences*, vol. cxii. pp. 233–236.
† *Journal of the Iron and Steel Institute*, 1887, No. II. p. 234.

Calorimetric Calculations.—H. von Jüptner * publishes a further series of articles relating to the method of calculation to be adopted in combustion experiments. The author takes as examples of such calculations—(1.) producer gas; (2.) waste gas from the stack, resulting from the combustion of the producer gas; and (3) a coal. The volumetric compositions of the gases are as follows:—

	CO.	CO_2.	O.	N.	CH_4.	H.
I.	26·00	4·05	0·21	56·86	0·35	12·53
II.	0·02	12·11	6·12	81·75	...	...

The coal contained—

C.	H.	O.	N.	Hygroscopic Water.	Ash.
75·56	3·61	9·23	0·76	1·56	9·28

The author then shows how much heat these fuels ought to yield, and what are the losses of heat by incomplete combustion and otherwise.

Pyrometric Data.—Mr. H. M. Howe † describes Le Chatelier's pyrometer,‡ which consists of a thermometric couple of platinum and an alloy of platinum and rhodium, connected with an aperiodic galvanometer, such as that of Deprez and D'Arsonval. The wires are very thin, so that they speedily attain the temperature to be tested, and the galvanometer quickly comes to rest. The instrument is calibrated by means of known temperatures, and the plotted curve of these experiments is continued. This curve is very regular, and approximates to a straight line. A bibliography of this pyrometer is given, and a number of melting and boiling points of various substances and other temperatures.

The specific heats and calories developed by iron and nickel in cooling to 0° C. from temperatures up to 1200° C. are given, so that the temperature by calorimetric methods can be found.

The Mesuré and Nouel Pyrometer.—This pyrometer has already been described in this journal.§ C. von Ernst,‖ in discussing it, points out that it has been successfully introduced at a number of ironworks, and observes that in addition to the scale of degrees accompanying the instrument, which range from 40 to 62, representing temperatures

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 534–539, 541–544, 553–556.

† *The Engineering and Mining Journal*, vol. l. pp. 427–428.

‡ See Prof. Roberts-Austen's paper in this volume.

§ *Journal of the Iron and Steel Institute*, 1889, No. I., p. 251.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. 533.

of from 900° C. to 1300° C—cherry-red to white—the following are also stated to have been experimentally ascertained :—

Degrees on Scale of Instrument.	Represent Degrees C.
33	800
66	1400
69	1500

II.—*COAL.*

The Soluble Constituents of Coal.—It is a well-known fact that there is a series of substances, consisting of carbon, hydrogen, oxygen, and sometimes also of nitrogen and sulphur, which occur in association with coal in almost all districts. Few of these, however, have been investigated. In the Westphalian collieries only one such body has been accurately determined. The material investigated by P. Siepmann * was a gas-coal from the Pluto Colliery in Westphalia, having the following composition, calculated for coal free from ash :—

C.	H.	O+N.	S.
80·31	5·50	12·94	1·25

The portion soluble in chloroform was found to contain :—

C.	H.	O.	N.	S.	Total.
83·46	7·93	4·27	2·71	1·63	100·00

By treating the coal with ether, alcohol, and chloroform consecutively, three different substances were obtained. In ether 0·30 per cent. was soluble, the resin obtained giving on analysis :—

C.	H.	O.	Total.
84·82	10·51	4·67	100·00

The extract, free from the insoluble portion, and dissolved and separated out several times, gave on analysis the following results :—

C.	H	O.	Total.
78·74	9·64	11·62	100·00

Exactly similar results were obtained from the bituminous coal from the Victor Colliery at Castrop in Westphalia.

The amount of the coal found to be soluble in alcohol was 0·25 per cent. The soluble substance was free from sulphur and nitrogen, and gave on analysis—

C.	H.	O.	Total.
72·52	10·08	17·40	100·00

* *Zeitschrift für das Berg- und Hütten- und Salinenwesen im preussischen Staate*, vol. xxxix. pp. 26–31.

The residue, when treated with chloroform, yielded 0·75 per cent. of a dark brown mass with a faint odour of coal-tar. On analysis it yielded—

C.	H.	O.	S.	Total.
78·82	8·56	9·97	2·65	100·00

The Coalfield adjoining Barnsley.—The Barnsley bed in the vicinity of Barnsley, according to Mr. R. Miller,* is exhausted, but sections and sinkings prove that several other beds exist below, although they have not been worked in this district on account of difficulties with the water. The author proposes to utilise the shafts already sunk, and their machinery, and to sink to the deepest of the seams, for pumping out the water. After the shafts have been lined with tubbing, no more water will have to be pumped below the Barnsley bed, and the six or seven seams lying below that bed could then be worked. These seams and their thickness are:—Swallow Wood, 3 feet; Lidget, 3¾ feet; Flocton, thick, 2¾; thin, 3 feet; Fenton, 8 feet; Parkgate, 5 feet; Thorncliffe, thin, 4½ feet; Silkstone, 5 feet; Whinmore, 3 feet. They lie at 60 to 435 yards below the Barnsley seam.

There was some question as to the feasibility of tubbing out water at the depth mentioned of 226 yards.

Coal in Baden.—H. Ott † endeavours to direct attention to the south-eastern edge of the Black Forest as a probable source of coal. Numerous unsuccessful explorations have been made on the southern and eastern edges. The fact, however, that the Triassic rocks and the Red Sandstone are deposited in the form of a basin in the area he indicates, appears to him to conclusively show that coal will be found below them. Experience has shown that the thickness of coal seams is in an inverse ratio to the area of the basin in which they have been formed. The author, therefore, concludes that coal will be found in considerable thickness in this small basin. Calculations are given of the probable amount of coal, and the national importance of the discovery, if it should be made, to the prosperity of South Baden is discussed. It must, however, be pointed out that no borings have yet been made, so that the author's calculations are somewhat premature.

* *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 7-10.
† *Die Möglichkeit des Vorkommen von Steinkohlen im Badischen Oberlande.*

Lignite Deposits in the Tyrol.—M. von Isser* states that borings which have recently been made in the neighbourhood of Hopfgarten, in the Tyrol, have led to the discovery of two large deposits of lignite. One of these has a length of about a mile, and a breadth of a third of a mile, with a thickness of 6 to 8 feet. The second, while of somewhat greater length, is slightly narrower, and of about the same thickness. The deposits have a S.—N. strike. They are bounded on the north by Triassic limestone, in the east by red sandstone, and in the south and west by clay slate.

Lignite of Cilly, Styria.—According to Lüddens,† numerous tree trunks and roots are met with in the lignite of Cilly. In some cases the trunks are as much as 10 yards in length. The lignite is used as fuel, whilst the trunks are used for the manufacture of pyroligneous acid, and the roots for that of illuminating gas.

Analyses of Lignite.—Dr. E. Prziwoznik ‡ gives the following analyses of lignite :—

	a.	*b.*	*c.*
Water	19·20	9·15	15·60
Ash	11·20	13·45	8·90
Carbon	47·20	49·10	51·60
Hydrogen	4·25	4·23	4·10
Oxygen and nitrogen	18·15	24·07	19·80
Totals	100·00	100·00	100·00
Calorific power in calories	4246	4158	4586

a. From the Dodosi Mine, Kralyercani; *b.* from Ilz, near Fürstenfeld; *c.* from Csaladudve-Zwierzina-Féle Mine in Nagy-Kovacsi, Hungary.

Coal in Servia.—In the south of Servia, and notably at Senje, near Cupria, rich beds of workable coal occur. At Senje the coal is 12 to 40 feet in thickness, and the amount available is estimated at 4,200,000 tons. The deposit is the property of the State. The coal is a black lignite, containing—

Carbon.	Hydrogen.	Oxygen + Nitrogen.	Ash.
70·34	4·57	20·73	4·05

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 71.
† *Chemiker Zeitung*, 1891, p. 120.
‡ *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxviii. p. 419.

The yield of volatile products amounts to 43·28 per cent., and that of coke to 56·72 per cent. The calorific power of the coal is 5545 calories.

The Alexinatz bed of coal is of less value. It is 3½ to 5 feet in thickness, and is only adapted for household use. Above this coal, however, there are valuable beds of paraffin shale. Throughout the whole of Servia but little has as yet been done to develop the important mineral resources of the kingdom.*

The following are assays of coal from the Senje district, Servia: †—

	Coke.	Volatile Matter.	Ash.	Calories.
1.	46·88	36·15	4·05	4910
2.	47·00	36·72	2·65	4876
3.	...	...	3·67	5285
4.	51·70	34·64	1·23	5081

The complete analysis of these samples showed, in addition to the ash:—

	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Moisture.
1.	58·12	3·78	20·73	13·32
2.	59·01	3·54	21·17	13·63
3.	59·85	4·44	19·41	12·63
4.	60·85	4·02	21·47	12·43

Coal-Mining in British Columbia.—According to Mr. A. Dick ‡ the prospects of coal-mining in British Columbia for 1891 are good, in spite of the recent strikes. His report deals with the various pits of the Nanaimo, Wellington, East Wellington, and Union Collieries. Several exploratory bore-holes just put down by the New Vancouver Coal Mining and Land Company have discovered one or two seams of workable coal near Nanaimo, and explorations made in the upper part of the Comox Valley indicate the extension of the coal-bearing strata. On Tumbo Island coal has also been found.

* *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 440.

† *Mining Journal*, vol. lxi. p. 225.

‡ *The Canadian Mining and Mechanical Review*, vol. x. pp. 92-94.

The Pictou Coalfield.—Mr. H. S. Poole * in dealing with the surface geology of the Pictou coalfield, Nova Scotia, states that boulder clay covers a great portion of the field. In the clay, fragments of coal are frequently noticed, and in one case a drifted mass of coal and shale 30 feet wide by 2 feet thick was found. The drift lies in ridges running about N. 40° E., and does not seem to depend on the formation of the subadjacent surfaces. The McCulloch's Brook fault of 2600 feet, which separates the Westville from the Albion field, has had some effect on the surface formation.

Coal in Victoria.—Mr. J. Stirling † states that the brown coal at Avon River, in Victoria, probably lies under the whole valley. It is similar to and contemporaneous with the deposit at Morwell in the Narracan Valley. The coal at Korumburra has been prospected. Near the outcrop it is much broken, but a shaft has been sunk to strike the seam at a depth of 101 feet, the coal dipping at 27°. Several thin seams of good coal were passed through, and the main seam was 3 feet thick. The coal is a coking coal of good quality, and resembles that at Jumbunna.

Coal in New Caledonia.—A report recently issued by the French Colonial Office deals with the geology and mineral resources of New Caledonia. Carboniferous strata are found over a considerable area on the west coast. They occupy a narrow zone comprised between the serpentinous formation and the eruptive rocks which border the sea. Outcrops of coal occur at the foot of Mont d'Or, on the Bay of Boulari, on the plain of St. Louis, and up to the environs of Noumea; in fact, they exist almost all over the west coast. For a long time attention has been directed to these beds, and they have been the object of special study. The Porte de Fer bed, situated about 2½ miles from Noumea, contains coal of good quality. Trials made in 1887 and in March 1888, on board vessels on the station, proved that this coal was sufficient for the service of the fleet, and at least equal to the best Australian coal, over which it has the advantage of giving only a whitish smoke, small in quantity.‡ According to another opinion, this coal gives little smoke, contains no pyrites, and gives a light non-clinkering ash, but that it would preferably be

* Paper read before the Nova Scotia Institute of Science, through the *Canadian Mining and Mechanical Review*, vol. x. pp. 38–39.

† *Report of the Victorian Mining Department.*

‡ *The Colliery Guardian*, vol. lxi. p. 714.

used mixed with other and better coal. An experiment as to the calorific power of Porte de Fer coal places it near that of Anzin. In the coal basin of Ourail or Moindou search has led to the discovery of eight seams of good quality, representing a total thickness of coal varying from 26 to 39 feet. The chances of working the coal are much more favourable than formerly, and this industry, at present in an embryo state, appears to have a future before it.

The South African Coalfields.—Mr. W. Galloway * gives a geological and economical account of the South African coalfields, on which he has already issued a report.† On the west of the country the ground rises at an average of 6 feet per mile, on the east at 33 feet per mile, to the great plateau at a height of 4000 feet above sea-level. The coal measures do not exceed 1000 feet in thickness, and overlie conformably the older Karroo sandstones. Over the measures come 1500 feet of red and purple sandstones and shales, then 300 feet of the Cave sandstone, and then volcanic rocks consisting of columnar dolerite, which caps all the hills and spurs. Very few faults are to be found, and there are no considerable foldings or contortions. After describing the appearance of the country, the author deals with the seams of coal which have been opened. The workable seam is found about 300 feet above the base of the coal measures, and is traced from Indwe on the east to Molteno on the west. Much of the ground above this seam is hidden by volcanic rocks, so that outcrops are masked. These volcanic rocks have also, in many instances, converted the coal into a dull grey, lustreless anthracite. Sections of the seams at various places are given, and show that the coal contains a great many partings; at Indwe, for instance, there is only 3 feet 8 inches of coal in the workable part of the seam, which is 6 feet 10 inches thick. An account of some steam trials with these coals is also given.

Coal Deposits of the Transvaal.—According to Mr. C. J. Alford,‡ the coal-beds of the Transvaal form a series from 20 to 200 feet in thickness. The beds are of lenticular form, and vary in thickness from a few inches up to 30 feet. An analysis of a fair sample of coal from Middelburg gave—

Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Moisture.	Ash.
72·80	5·75	1·90	3·80	1·60	14·75

* *Proceedings of the South Wales Institute of Engineers*, vol. xvii. pp. 67-84.
† *Journal of the Iron and Steel Institute*, 1890, No. I. p. 228.
‡ *Geological Features of the Transvaal.*

In no case has any of the coal been found to yield a hard coke, such as would be suitable for metallurgical purposes. An analysis of coke made from Middelburg coal yielded—

C.	H.	N.	O.	S.	H_2O.	Ash.
74·58	0·50	0·30	0·10	4·20	0·40	20·00

The coal deteriorates very much from exposure, and should never be stacked in large quantities on account of its liability to spontaneous ignition.

The Darjiling Coal.—Mr. P. N. Bose * describes in detail the economic geology of the Darjiling coal between the Lisu and Ramthi rivers. Though noticed by Sir Joseph Hooker in 1849, no notice was taken of this coal until 1873, when the completion of the Northern Bengal State Railway gave it a new importance. In that year Mr. F. R. Mallet was deputed to examine the region, and his report was decidedly against the workability of the coal. The district has now been re-examined by the author, and the discovery of thick seams of caking coal appeared so promising that it was considered advisable to ascertain their extent by excavations.

The coal-bearing rocks consist essentially of sandstones and shales, the former predominating. The shales are, as a rule, more or less carbonaceous. Certain black shales, breaking with a conchoidal fracture, are highly carbonaceous, and it is in association with these that coal seams occur. Igneous rocks are of frequent occurrence. That the mica traps are intrusive is shown by the hardening of the sandstones, shales, or coal in contact. All the rocks have been greatly disturbed. The dip is seldom lower than 30°, and is usually very high. As a consequence of the disturbance which the beds have undergone, the rocks have been greatly crushed, the effect being specially noticeable in the shales and coal. The author describes various coal seams met with in the Churanthi Valley, the Ramthi Valley, the Chunkhola, and the Lisu Valley, giving a tabular summary of the principal coal seams, twenty-five in number, not less than 5 feet in thickness, leaving out those which have been too highly altered by contact with igneous rock to be of value.

With regard to quality, the coal may be classed under three heads:—

1. Cakes strongly. Percentage of ash not exceeding 16.
2. Cakes strongly. Percentage of ash between 16 and 22.
3. Does not cake. Percentage of ash between 22 and 33.

* *Records of the Geological Survey of India*, vol. xxiii. pp. 237–258.

Coal of the first class from Pit No. 3 (I.), and from Pit No. 1 (II. and III.), in the Lisu Valley, was assayed with the following results :—

	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.
I.	14·54	8·86	63·96	12·64
II.	4·72	22·16	60·24	12·88
III.	3·28	20·60	60·12	16·00

The first of these samples caked strongly, and formed a light tumescent coke. The coal from all these pits, taken from a depth of some 6 feet below the surface, gave similar results.

Coal of the second class gave on assay the following results :—

	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.
IV.	4·21	14·09	65·56	19·14
V.	16·10	15·47	51·85	16·58
VI.	20·80		57·92	21·28
VII.	21·48		56·52	22·00
VIII.	17·20		63·28	19·52

IV., Pit No. 7, Churanthi Valley, depth 9 feet. V., Pit No. 25, Chunkhola River, depth 7 feet. The remaining three samples (VI., VII., VIII.) are from Pit No. 7, Churanthi Valley, surface.

Coal of the third class gave on assay the following results :—

	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.
IX.	0·80	7·88	58·12	33·20
X.	1·60	10·40	61·76	26·24
XI.	5·76		69·84	24·40

Compared with the Raniganj coal (average of 31 assays), the Darjiling coal (average of 8 assays of coal of Classes 1 and 2) appears as follows :—

	Moisture and Volatile Matter.	Fixed Carbon.	Ash
Darjiling	59·56	22·94	17·43
Raniganj	53·20	30·63	16·17

The utilisation of the Darjiling coal depending largely upon its coking properties, practical tests were made in three kilns erected for the purpose. In each case, good coke, equal to that made at Barakar, was obtained, the coke containing but 0·62 per cent. of sulphur. The fact that so many of the outcrops have yielded good coke is the most hopeful feature about the coal.

With regard to the quantity of coal available, the author confines his calculation to the central portion of the explored area, which measures only 97 acres. Restricting himself to seams he has actually traced, and neglecting all coal with more than 22 per cent. of ash, he concludes that there is 5,592,645 tons of good coal almost immediately available. In these calculations the limit of workable depth is taken at 1000 feet. For the entire area explored, which measures a little over one square mile, the amount available must be much greater. A fair estimate would be 20 million tons of coal of Classes 1 and 2, or 30 million tons if the coal of Class 3 is also taken into account.

The coalfield is situated at a distance of 2½ miles from the Duars, and as there is only one made road in the explored area, it would be necessary to extend the Silliguri cart road to the coalfield. Carriage by the river Testa to Jalpiguri would be cheap. The coal could be carried down to the foot of the hills by a wire ropeway. The proposed Duars Tramway will pass at a distance of 10 miles from the coalfield, and a branch to it deserves consideration.

The coalfield is advantageously situated with reference to mineral resources. Seven miles to the north of it there are deposits of excellent iron ore, magnetite and micaceous hæmatite assaying 71·5 and 59·89 per cent. of iron respectively. There are also in the vicinity important deposits of copper ore, of arsenic, and of tufaceous limestone. The district is scantily populated, so that labour is scarce, and, if the coal be worked, Nepalese labourers will have to be obtained.

With regard to mining, some of the conditions appear to be in favour of the coal, but others are distinctly against it. Owing to the crushed condition of the coal, it can be easily dug out with picks, so that the cost of extraction would be much less than in the Raniganj and Giridih mines. On account of its high dip the coal has been brought to the surface, and consequently it will not, as a rule, be necessary to sink shafts through unproductive rocks. The powdery condition of the coal is favourable for coke-making, and water for the coke ovens can easily be obtained. On the other hand, owing to the crushing which they have undergone, the shales are not likely to

afford a firm roof in deep mining, and extensive timbering will be necessary.

The Coal Seam of the Dore Ravine, India.—In a preliminary note on the coal of the Dore Ravine, Hazara, Mr. C. S. Middlemiss * gives two sections of this coal seam, which has erroneously been described as lying with the adjacent limestones in the form of an anticlinal arch, cut through by the river action. As a matter of fact, the order of the strata on the left side of the section is not the same as on the right side. Indeed, the author shows that it is inverted. The difficulties implied by such a structure are fatal to the development of an important coalfield in this district. The author has, however, a sanguine belief that a large supply of serviceable coal may be obtained from the outcrops. The purely scientific aspect of the questions involved will be dealt with by the author in a subsequent report.

Assays † of coal from the Hertoh River, Hazara, gave the following results:—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.
3·04	9·80	80·86	6·30
2·94	5·08	11·86	80·12

Coal in Burmah.—According to the last annual administrative report, the coalfields in the Upper Chindwin district and the country between the Myittha and Yu rivers have been examined. The total area of the coalfield in this part of the country is estimated at 175 square miles. It consists of two portions—the more valuable one, near the river, measuring about 55 square miles, and the other about 120 square miles. The coal occurs in Tertiary strata of very regular bedding; the seams are numerous, but the majority of them are not thick, few exceeding 3 feet, only one measuring 10 feet. The coal is of good quality, hard and bright, and makes excellent fuel. The average of eleven analyses of Chindwin coal shows a percentage of fixed carbon of 49·95. Some seams, however, show as high a percentage as 65·59. The borings at the Thayetmyo coalfields have been stopped, and it is unlikely they will be taken up again. In the Northern Shan States coal has been found near Lashio, in isolated basins varying in extent. It occurs in Tertiary sandstone surrounded by Silurian limestone. The outcrops are difficult to examine, being situated in the beds below the water-level nearly the whole year

* *Records of the Geological Survey of India*, vol. xxiii. pp. 267-269.

† *Ibid.*, p. 272.

round. In the Lashio coalfield there is one seam of at least 30 feet in thickness. This has been superficially traced for more than two miles. The coal is not of the first quality, being very light and liable to crack when dry. In the Nammra basin there are numerous coal-seams, ranging mostly from 6 to 8 feet in thickness. In several of them the coal is of a very hard description; but it is, comparatively speaking, poor, the percentage of fixed carbon not exceeding 39 in any one of the eleven samples tested.*

The Coalfields of the Northern Shan States.—In a report by Dr. Nötling † on the coal measures of the region between the Irrawaddy and the Salween, assay results are given which relate to twelve samples of lignite. Considerable uniformity existed among the samples examined, the average composition being :—

Fixed Carbon.	Volatile Matter.	Ash.
39·94	50·40	9·67

The coal of the Southern Shan States contains from 64 to 70 per cent. of fixed carbon.

Coal in Tonquin.—Mr. W. Warren ‡ gives some information regarding the coal deposits of Tonquin. The seams crop out round the bases of the low hills which fringe the Gulf of Tonquin. One of the seams is 152 feet thick and is of nearly solid coal. It is semi-anthracite of good quality, containing about 87 per cent. of fixed carbon, from 7 to 12½ per cent. of volatile matter, and from 2 to 3 per cent. of ash. It is free from pyrites. The results of some ship trials have proved satisfactory, and the coal is greatly superior to that of Japan, which contains 23 to 27 per cent. of ash.

Coal in China.—The Viceroy of the Liang Hu provinces has recently issued a proclamation to the effect that he is prepared to find an outlet for all native coal, and recommending the purchase of foreign pumps to drain the pits, so that coal other than that at the surface can be mined. Similar proclamations have been issued in other provinces. Up to the present but little coal mining has been done in China, although a large quantity is mined in Japan, and exported to China and Australia.

China undoubtedly possesses coalfields of considerable extent and

* *Colliery Guardian*, vol. lxi. p. 276.
† *The Mining Journal*, vol. lxi. p. 599.
‡ *Engineering*, vol. li. p. 80.

value, and more or less recent explorations show that they exist in almost every part of the empire. Native industry and imported machinery only are required to make the coal industry succeed. Many of the old seams, where the mines have been abandoned, are to be worked forthwith, while new shafts are to be sunk wherever it is considered probable that mines can be successfully started. Explorations have disclosed the existence of a vast coalfield, extending from the sea at Jih Chaou to the dividing range of mountains a hundred miles inland.

Coal seams of great thickness are found at or near Pin-yang, where mining operations have also been commenced on an extensive scale. Another large coalfield is situated near Lantchou, where at the present time twelve mines are in operation. The coal is generally procured with very little trouble near and at the surface. In consequence of the increased demand, and the inducements put forward by the Government to encourage them in their efforts to develop coal-mining in China, a party of Chinese speculators have lately commenced operations in this district. They have completed a tramway, 2 miles in length, to a pit where the working of a seam of superior coal 11 feet thick has been commenced. This seam lies at a depth of only from 20 to 25 fathoms below the surface. In another coalfield, about 40 miles to the south of this, it is stated that there is one seam of solid coal cropping out 34 feet thick, and of very superior quality. Not far from here are the Tie-choo mines, where, however, only two shafts, out of nine in existence, are being worked. The quality of the coal is fairly good, and the output from these two shafts is about 2000 tons per month. It is probable that the other seven shafts on this property will soon be put in working order, and operations resumed on an extended scale. Experiments have been made by direction of the Government as to the practical value of native coal taken from mines in Southern China. The Yún-nán-fou coal is usually of a brilliant black colour, tolerably hard, and of an approximate density of 1·2. It must be classified among the anthracites. It crumbles when exposed to the air for any length of time. It is of remarkable purity, possesses considerable heating power, but produces no coke, and in order that the Yún-nán-fou coal may be taken into general use, it is in the highest degree important that a system of picking on the floor of the mine should be adopted. Coal of similar quality, and possessing very much the same characteristics and properties as the Yún-nán-fou coal, is also being mined at Si Kiang, and

with a special kind of furnace with a powerful draught, it will prove an excellent steam coal.*

Alabama Coalfields.—The three principal coalfields of Alabama, the "Warrior," the "Cahaba," and the "Coosa" fields, are described by Mr. C. R. Claghorn. The special features of the Warrior field, 7810 square miles in area, are, first, a tendency in all coal seams to thin going north-west from the south-east outcrop, a line of average thickness crossing the field diagonally in a north-east and south-west direction; second, an increase of hardness in the same direction, with a corresponding decrease of coking properties, so that the typical coking and smithy coals are mined along the south-east outcrop, whilst the best domestic and shipping coals come from the centre and west; third, a nearly constant chemical composition, commercial lots averaging—fixed carbon, 55 per cent. to 63 per cent.; of volatile matter, 28 per cent. to 34 per cent.; ash, 5 per cent. to 10 per cent.; and sulphur, 0·5 per cent. to 2 per cent. The moisture in all Alabama coals is low. The Cahaba field, as at present developed, produces the most satisfactory fuels in the State; but in the northern end of the basin the coal appears dirty and slaty, and the productive areas in the south end are limited by reason of high dips and the broken and disturbed condition of the measures. The Coosa field has only two active collieries, which, in point of production, are of minor importance. The coking coals of the district will naturally continue to be drawn from the present developed areas. The needs of the district for domestic and steam coals will best be met by the construction of a north and south railroad from Tuscaloosa, passing through the heart of a rich coal area, where the measures are thickest and the coals situated favourably for economical mining.†

The Pratt Mines, Alabama.—Assays of the three representative coals of the Alabama field, as given by Mr. E. Ramsay,‡ show:—

	Pratt.	New Castle.	Black Creek.
Specific gravity	1·299	1·33	1·36
Sulphur	1·041	0·64	0·10
Moisture	1·025	0·50	0·12
Volatile matter	32·169	28·24	26·11
Fixed carbon	63·370	59·69	71·64
Ash	3·342	10·92	2·93

* *The Colliery Guardian*, vol. lxi. p. 63.
† Paper read before the Engineers Club of Philadelphia, April 4, 1891.
‡ *Transactions of the American Institute of Mining Engineers*, vol. xix. (advance proof).

Jefferson County, in which the Pratt Mine is situated, yields nearly three-fourths of the coal in this State. This mine was first opened in 1879, and has been gradually enlarged to supply the neighbouring iron furnaces. The seam outcrops at an angle of about 20°, but the dip decreases farther in. The coal is taken out through haulage slopes driven under the seam, but at a less angle, and continued in the coal when they meet. The plan of working first adopted was a kind of pillar and stall, but much of the coal had to be abandoned in the ribs. Under the present system, galleries are driven at about water-level off the main slope at intervals of 300 feet, and the intervening body of coal is worked out by first driving stalls 40 feet wide and 60 feet from centre to centre for a distance of about 275 feet. This leaves a pillar of 20 feet between the stalls, which is drawn back to the heading as soon as the stalls are finished. In this way all the coal is taken out between the headings, leaving pillars to protect the entries. When the stall headings have been driven to their destination, usually 3000 feet, these pillars are removed. By this means not more than 5 per cent. of the coal is lost. But little water is met with, and that is free from acid. Ventilation is usually performed with one continuous current, but in two of the slopes a split current system is used. A fan of the Guibal type is placed at the air shaft on each side of the main haulage slope, so that the ventilation of each side is quite distinct, and each stall heading takes its supply of fresh air direct from the main slope.

The seam is remarkably uniform in quality and thickness, averaging 4½ feet. The roof is hard sandstone, which requires but very little propping. The usual method of mining is to undercut about 3 feet and to shear along the side or rib, and the coal is then blasted down. Most of the mining is done by hand, but there are thirteen Harrison pick machines which hole to a depth of 4½ feet along 90 feet with one man per shift. The coal is freed from slate and loaded into 25 cwt. trucks, which are taken up the slope two at a time by direct-acting winding engines. The arrangements for dealing with the trucks at the surface are also shown; the full trucks run by gravity to the dump, and are conveyed back by a second inclined plane to the pit mouth. Where power haulage is used underground, a tail rope system is employed. Two batteries of two cylindrical boilers, 24 feet by 46 inches in diameter, are situated at the bottom of an air shaft, 360 feet deep, to save raising their fuel. Waste heat from the boilers aids ventilation. The pumps are placed near the boilers, and the water is

brought to them through a ditch 10 feet deep, which gives ample storage capacity.

A description of the coke-making plant is given, and it is stated that the output of these mines has risen from nearly half a million tons in 1883 to 1,084,784 tons in 1889.

Coal in Alaska.—Mr. I. Petroff* in a recent report states that coal has been discovered in various parts of the territory of Alaska. Up to the present only lignite has been found, but some of it is of the best quality. Only one seam has been worked to any extent, and this seam is situated at Hereenden Bay, on the north. Some seams near Cape Lisburne supply coal to passing vessels, and another seam is being prospected at the mouth of Cook Inlet. On the island of Unga there is a coal seam of considerable extent. There had been at one time considerable workings by the Russians in English Bay.

Coal from Colorado.—According to Mr. J. W. Nesmith,† a coking coal from Colorado gave the following results on assay :—

Fixed Carbon.	Volatile Matter.	Ash.	Water.
67·06	28·39	3·37	1·18

The coke produced contained 0·37 per cent. of sulphur.

An anthracitic coal from the same district gave :—

Fixed Carbon.	Volatile Matter.	Ash.	Water.
89·76	5·66	3·00	1·58

The Dan River Coal Basin in North Carolina.—According to Mr. H. B. C. Nitze,‡ the Dan River coal basin in North Carolina is 35 to 40 miles long by 3 miles broad. It belongs to the Triassic formation. As many as seven or eight seams of coal have been found; but there are not more than three workable. The highest seam has about 3 feet of impure coal, the next seam is 4½ to 5½ feet thick, and the bottom seam is from 2 to 3 feet thick. The coal is mostly very soft and friable, but it is possible that it may improve in the deep. Several workings have been carried on. An assay of a picked sample by Mr. H. M. Chance shows :—

Moisture.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.	Total.
3·70	4·67	81·58	2·23	7·82	100·00

* Census Report, through *The Engineering and Mining Journal*, vol. li. p. 373.

† *Iron Age*, vol. xlvii. p. 1077.

‡ Mineral Resources along the Route of the Roanoke and Southern Railroad, through *The Engineering and Mining Journal*, vol. li. p. 448.

Exploration with the diamond drill is needed, as the district contains many rich deposits of magnetite.

Coal in North Dakota.—Professor Babcock * in a recent report states that the general direction of coal deposits in North Dakota seems to be north and south. There are three seams visibly outcropping in the valleys. The lowest is at a depth of 50 to 200 feet, and varies from 7 to 20 feet in thickness. Fifteen feet above this is a second seam, 18 to 36 inches thick; and a third seam, from 1 to 2 feet in thickness, is found above.

The Log Mountain and Clear Creek Coal Region.—Bell County, Kentucky, contains a coal basin known as the Log Mountain and Clear Creek deposit. Professor A. R. Crandall † states that one seam is analogous to the cannel coal of the adjoining Whitley County. It has a slate roof, 24 inches of coal and 45 inches of cannel coal at the bottom. Assays of the two parts of this seam show:—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
1·70	32·60	62·30	3·40	0·684
1·00	51·60	40·40	7·00	0·739

In the 300 feet above this seam, corresponding to the horizon of the Jellico coal, only thin seams are found. The next bed of importance is the "Poplar Lick," about 4 feet thick, which shows on assay:—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
1·00	34·40	59·40	4·60	0·682
1·80	33·00	60·10	5·10	0·656

The coke from this seam has a firm columnar structure, and contains 8 per cent. of ash, and 0·693 per cent. of sulphur. Next above comes the "Hignite" coal, of which there are two seams—the lower about 44 to 46 inches, and the upper about 52 inches thick. Assays of samples from various localities show:—

	Polk Branch.	Partin's.	Laurel Branch	Piney Spur.	Sugar Camp.	Stoney Fork.
Moisture	2·20	2·30	4·90	1·66	2·66	3·00
Volatile matter	33·40	33·90	29·54	33·40	34·14	31·96
Fixed carbon	61·60	60·40	62·36	61·52	59·70	62·04
Ash	2·80	3·40	3·20	3·48	3·50	3·00
Sulphur	0·601	0·629	0·78	0·794	0·840	0·478

* *American Manufacturer*, vol. xlviii. p. 204.
† *Ibid.*, vol. xlviii. p. 261.

Assays of the coke are as follows :—

	Piney Spur.	Sugar Camp.
Volatile matter	0·43	0·39
Fixed carbon	91·87	92·61
Ash	7·71	7·00
Sulphur	0·637	0·530

About 450 feet above the Hignite coal is the Red Spring seam of about 55 inches thick. Assays of the coal from this seam are as follows :—

Moisture	3·40	3·40	2·20	2·60
Volatile matter	31·60	32·40	34·20	33·20
Fixed carbon	58·24	59·20	60·40	60·20
Ash	7·80	5·00	3·20	4·00
Sulphur	0·601	0·563	0·576	0·670

The coke contains 91·16 per cent. of fixed carbon, 8·50 per cent. of ash, and 0·416 per cent. of sulphur.

The Middlesborough Coalfield, Kentucky.—A map and section of the coal district of Middlesborough, Kentucky, are given by Mr. J. A. Jardine and Mr. O. W. Davis.* On Bennett's Fork there are eight seams outcropping at heights from 600 to 1200 feet above water-level, and ranging in thickness from 2 to 6 feet, with an aggregate thickness of about 33 feet. On Stoney Fork there are similarly seven seams, ranging from 8 inches up to 3½ feet. Up to the present the development has been confined to the Ralston seam, which yields 58 to 60 inches of solid coal with two partings. The seam is undercut in the upper 8-inch parting, and the top bench falls by its own weight, while the lower ones are wedged up. Assays of the coke made from the coal of this seam show :—

Water and Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	Phosphorus.
1·30	91·89	6·70	0·688	0·018
3·05	90·51	5·89	0·550	...

Other assays of the coal from this seam show :—

Moisture	...	1·95	2·15	1·95	1·29
Volatile matter	38·10	39·10	38·30	40·95	31·91
Fixed carbon	59·50	55·50	57·95	55·15	65·12
Ash	2·40	3·45	1·60	1·95	1·40
Sulphur	...	0·494	0·418	0·611	0·38

* *American Manufacturer*, vol. xlviii. p. 241.

Coal in New Mexico.—The extent of the coalfields of New Mexico is not generally known. The Raton fields, an extension of the Colorado fields, embrace about 600,000 acres of the best bituminous coal, of good coking quality. The mines have now a capacity of 500 tons per day. There are also other coalfields. The hills are full of undeveloped deposits of iron ore, with coal enough to work them.*

The Coalfields of Texas.—A recent report contains some very interesting facts about the coal measures of Texas. The main seam of bituminous coal is first met with in the northern part of the State, and extends south-west from a point on Red River, in Montague County, to the Colorado, being a continuation of the western field, of which it is the southern boundary. This deposit underlies twenty-five counties, and covers an area of 12,000 square miles. Hitherto this deposit has been unworked, with the exception of that portion situated in Erath County, which has been developed on a small scale by the Texas and Pacific Coal Company. The deposit ranking next in importance is situated on the Rio Grande River, and underlies Medina, Zavalla, Webb, Uvalde, Maverick, and Dimmit counties, embracing an area of 3700 square miles, and is known as the Neuces coalfield. The coal mined is of a semi-bituminous character in the lower strata, whilst in the upper strata it is of the lignite order. The principal developments are at Santa Tomas, in Webb County, near Laredo, and at Eagle Pass, in Maverick County. Large deposits of lignite are found in Red River County, extending south-westerly to the Rio Grande, and north-east to the Sabine, in Sabine County, the only developments thus far made being in Rains County. The quantity of coal mined in Texas during the years 1888 and 1889 aggregated 128,216 tons, and its value is estimated at about £68,000.†

The Flat Top Coal Region.—After the first opening of a coal mine in South-West Virginia about eight years ago, the development of the region proceeded rapidly. An assay of the Flat Top coal shows:—

Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
1·01	18·81	74·26	0·73	5·19

On the No. 3, or Nelson seam, there are seventeen companies at work, and some 35,000 to 40,000 tons are exported from the district,

* *Industries*, vol. x. p. 332.
† *Age of Steel; Industries*, vol. x. p. 524.

besides what is made into coke. There are 2138 coke ovens in operation, and 647 building. At Coaldale, 150 ovens are of the "Anchor" pattern.*

Coal in Guaymas.—Veins of iron and deposits of coal are found in different parts of the Guaymas district, Mexico, but are not developed.† The coal deposits have been worked to a small extent to supply fuel for the steam works of the mining companies in the immediate neighbourhood. This coal (anthracite) is said to be abundant and of good quality, containing from 80 to 90 per cent. of fixed carbon. The seams vary in thickness from 4 to 10 feet. These deposits can be reached from the coast over easy gradients. The coal used by the Lodora Railroad is brought from Blossburg, New Mexico. Steam vessels obtain their supply principally from San Francisco and from Mazatlan. Concessions of mineral lands, under the federal law of 1887, have not given the results that were expected as to the development of certain parts of the country known to be rich in minerals.

Coal in Brazil.—According to M. H. Jorceix,‡ the carboniferous measures exist in the provinces of Para, Amazon, Santo Paulo, Parana, Santa Catharina, and Rio Grande do Sul in Brazil. Up to the present, exploratory boreholes have not reached coal, however, in the first two of these districts. At Tatuhy, in Santo Paulo, coal crops out at the surface, and a few thin seams have been discovered by boring. At Santa Catharina, near the river Taburo, there is a basin of good bituminous coal, and similar deposits are found in the valley of the Ararangua. Rio Grande do Sul appears to be the richest in coal, and contains several basins which have been proved to a certain extent. One basin contains coal of 1·24 to 1·3 specific gravity, which yields 60 to 63 per cent. of coke. The Arroio dos Ratos deposits have been worked for several years. Briquettes are also made in this district.

The Manufacture of Briquettes.—E. Schenk zu Schweinsberg § describes the manufacture of briquettes, pitch being used as a binding material. The success of the work depends (1) on the amount of pressure to which the briquette mass is subjected; (2) on the quality

* *American Manufacturer*, vol. xlviii. p. 181.

† *The Colliery Guardian*, vol. lxi. p. 714.

‡ *Le Bresil en* 1889, through the *Iron and Coal Trades Review*, vol. xlii. p. 296.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 463–468, 482–485.

and character of the raw material used, both coal and pitch; and (3) on the temperature to which the briquette mass is raised before it is subjected to pressure. This heating is performed by the aid of superheated steam.

With regard to the degree of pressure to be employed, the author observes that as soon as the mass of coal and pitch has been raised to the requisite temperature, and has become soft, plastic, and well mixed, it is placed in the press. The pressure to be exerted depends on the size of the briquettes in course of manufacture. These are usually broadly divided into large and small; the former weigh from 10 to 20 lbs., the latter less than 10 lbs. Hard coals usually require a greater pressure than soft coals. For large briquettes, a soft coal being used, the pressure should not be less than 1400 lbs. per square inch, and with hard coals half as much again. In the former case the maximum pressure should be about 2100 lbs., and in the latter 2800 lbs. For small briquettes lower pressures may be employed, but under no circumstances should it be less than 700 lbs.

The coal used in the manufacture of briquettes should be as free as possible from ash. Bituminous coals are found by practice to require from 1 to 2 per cent. less pitch than do non-bituminous coals; but this again is dependent on the size of the coal smalls used, and on the percentage of moisture they contain. The best mixture is one consisting of coal of a size small enough to pass through a sieve of 0·16 inch mesh, and of coal which will not pass this screen but which will go through a mesh of twice the diameter. The proportions employed would be from two to three parts of the first to one of the latter, according to the character of the coal. A low percentage of moisture in the coal is not without its advantages in pressing, but it should not exceed 3 per cent. if the steam used has a temperature of at least 150° C. or less, and it should not exceed 2 per cent. if the steam used has a temperature below 150° C.

The pitch used should possess good binding qualities. Unfortunately it is not as yet possible to foretell from the chemical composition whether a pitch will possess these or not. The author then proceeds to describe the pitch used, and to discuss the temperature and tension of the steam employed.

P. Rossigneux * discusses the manufacture of briquettes at considerable length, both from the historical and practical point of view. The use of the various agglomerating agents, molasses, guttapercha, tar,

* *Génie Civil*, vol. xviii. pp. 114–117, 136–139, 147–149, 163–167, 184–187, 202–204.

&c., is referred to, but it is shown that pitch is the only one which is of practical value. A curve is given showing the relative influence of the addition of varying quantities of pitch. Below 4 per cent. the briquette shows little cohesion, from this to 9 per cent. the cohesion rapidly increases, but beyond this limit the increase is but slight. The furnaces and apparatus used in the manufacture are discussed in detail. The cost of manufacture is given as about one shilling per ton.

At the Sayton collieries,* distant fifteen miles from Richmond, Virginia, the culm is mixed with pitch, and is then passed through rolls, using considerable pressure. An egg-shaped ball, termed "eggette," is thus obtained.

III.—*COKE.*

Coke-Making in South Australia.—At Port Pirie, Spencer's Gulf, South Australia, there are at the present time forty-two coke ovens in operation. The monthly outturn is 300 to 400 tons. The coal is crushed in a Carr's disintegrator, and carried by a conveyor to bins, whence it is transferred to the ovens in trucks. The ovens are of various sizes, and no by-products are recovered. Ten ovens carry a charge of ten tons, the others average only 3 to 5 tons. The coke is said to contain 2 to 2½ per cent. of ash.†

Coke Ovens in the United States.—According to Simmersbach,‡ the coke ovens in use in the United States are almost exclusively of the old beehive type of 10½ by 12 feet in diameter, and 5 by 7 feet in height. The method of coking and the coking plants in the various coal-fields are described in detail by the author. In conclusion, he gives the following analyses of the coke:—

	Connellsville.	Pocahontas.	Chattanooga.	Birmingham.
Carbon	89·576	92·585	80·513	87·300
Volatile constituents	0·460	0·494	1·101	0·803
Water	0·030	0·196	0·447	0·157
Ash	9·113	6·048	16·344	10·545
Sulphur	0·812	0·677	1·595	1·195

* *Iron Age*, vol. xlvii. p. 1111.
† *Engineering and Mining Journal*, vol. l. p. 740.
‡ *Glückauf*, 1891, No. 12.

Coking at Lake Superior.—The Lehigh Coal and Iron Company have erected fifty new coke ovens at West Superior, Wisconsin. This is at present the only plant making coke on Lake Superior; its annual capacity is about 60,000 tons. The first ovens were built in 1888. The position of the plant is of importance, owing to the adjacent iron ore deposits. No blast furnaces have, however, as yet been erected in this neighbourhood.*

The Coke Industry in Alabama.—During 1890 it is reported that 1155 coke ovens were built in Alabama, this being an increase of 25 per cent. over those in work in the previous year. The number now built is about 6000. The largest company owns 1222 ovens, the next in order possess 1120, 1056, and 750 ovens. All the present ovens are of the beehive type, except sixty-four, which are of the "Thomas" pattern. The coke is chiefly made from unwashed coal. The following are typical assays: †—

Moisture	0·25	0·16	0·15	0·09	0·41	0·45
Volatile matter . .	0·40	1·19	1·12	3·32	1·93	1·57
Fixed carbon . . .	92·33	86·74	90·46	81·51	85·01	85·02
Ash	6·21	10·82	6·66	11·81	12·25	12·96
Sulphur	0·82	1·08	0·66	1·34	...	1·87

Coke Oven Plant of the Pratt Mines, Alabama.—In the course of a description of the Pratt mines in Alabama, Mr. E. Ramsay ‡ states that the coke plant consists of 806 ovens. They are mostly of the beehive type, 12 feet in diameter and 6 feet high in the clear. They are charged by "lorries," each containing one charge, and running on 5-feet gauge overhead tracks. The lorries are supplied from bins. The oven charge is 5 tons, and the yield 3 tons of coke. The coke compares favourably with the Connellsville coke, but is higher in ash and other impurities. Several attempts have been made to wash the coal before coking, but without successful results.

Coke Making in Western Kentucky.—Mr. J. B. Atkinson § describes the efforts made to produce coke free from sulphur from the

* *Iron Age*, vol. xlvi. p. 1126.
† *American Manufacturer*, vol. xlviii. No. 1.
‡ *Transactions of the American Institute of Mining Engineers*, vol. xix. (advance proof).
§ *Engineering Association of the South West; American Manufacturer*, vol. xlviii. p. 161.

Western Kentucky coals. The two chief seams in this district are fairly constant in quantity, and contain 5 per cent. of ash with 2·9 per cent. of sulphur, and 6 per cent. of ash with 2·5 per cent. of sulphur, respectively. Most of this sulphur appears to be chemically combined with the carbonaceous part of the coal, as it is not eliminated by washing out the ash. The lower seams of coal are also heavily charged with sulphur, and also vary considerably in their composition. Up to 1888 about forty beehive ovens had been built in the district, and the author made experiments to reduce the percentage of sulphur. In no district where coke manufacture was carried on could he find any successful experiments in reducing the amount of organic sulphur. Air cooling, water quenching, steam quenching, or the introduction of steam into the coal during coking, all had about equal effect. Other trials were made by quenching with a solution of manganese chloride; salt, fluorspar, or limestone was added before coking, but none of these had any effect. At Earlington the coal is washed in trough washers and then in jigs. An assay of the coke from the washed coal shows:—

Moisture and Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
1·35	87·03	12·63	2·53

A sample from a pile that had been exposed to the weather for nine months contained:—

Moisture and Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
2·74	82·58	14·68	1·28

This sample was used in a blast furnace, and the pig iron contained:—

	No. 1.	No. 2.	No. 3.
Carbon	4·64	3·88	3·94
Sulphur	0·43	0·61	0·49
Phosphorus	1·25	1·24	1·44
Silicon	2·67	2·62	2·21

Coke from American Coal.—The following assays show the compositions of various varieties of American coke: * —

	Average Composition.		
	Fixed. Carbon.	Ash.	Sulphur.
Seven samples Big Stone Gap coke, Virginia, made in open rick and by barrel test . .	93·23	5·69	0·749
One sample Big Stone Gap coke, oven test . .	94·04	4·74	0·588
Three samples Connellsville coke, Pennsylvania, oven test	88·96	9·74	0·810
Four samples Chattanooga coke, Tennessee, oven test	80·51	16·34	1·595
Four samples Birmingham coke, Alabama, oven test	87·29	10·54	1·195
Three samples Pocahontas coke, Virginia, oven test	92·55	5·74	0·597
Eight samples New River coke, West Virginia, oven test	92·38	7·21	0·552

Coke in Virginia.—An assay of coke made in an experimental oven from coal mined at Big Stone Gap, Virginia, shows:—

Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
0·068	0·564	94·04	4·74	0·588

The colour of the ash is brown.†

The Simon-Carvès Coke Oven.—A number of illustrations showing the arrangement of this oven, and of the condensing plant for the collection of the by-products, appear in the *Iron Age.* ‡ The general features of the oven § are too well known to require description. The products of condensation are to a large extent collected in a depositing tank, whence the ammoniacal liquors pass into a saturating tank, and are then forced through scrubbers to collect the ammonia from the escaping gases. The gases so treated are next washed with heavy oils, which absorb the benzols, these being afterwards separated again by distillation. The separation of the tar from the ammoniacal liquor is effected by allowing them to stand for some time in a tank, the separation taking place through the difference in density.

* *Iron Age*, vol. xlvii. p. 149.
† *American Manufacturer*, vol. xlviii. p. 121.
‡ Vol. xlvi. pp. 1036–1038.
§ *Journal of the Iron and Steel Institute*, 1883, p. 494.

The interior dimensions of the Simon-Carvès oven are as follows:—Length, 23 feet; width, 18 to 20 inches; height, 6 feet 6 inches. The oven takes a charge of 5 tons. The coking requires about forty-eight hours, and with a charge yielding 75 per cent. of coke the daily outturn is about 2 tons of coke and 10 per cent. of ammoniacal liquor, 3 per cent. of tar, and 6½ to 9 lbs. of benzol per ton of coal.

Various estimates of cost accompany the description, a battery of fifty ovens costing about £10,000. Of this total the condensing plant required for the battery costs more than one-third.

Improvements in Coke Ovens.—L. Semet * has introduced a modification in horizontal coke ovens, which consists in the use of a pressure chamber for regulating the gas supply, and causing an even distribution of the gas in the various channels surrounding the ovens.

Utilising the Waste Heat from Coke Ovens.—M. Rossigneux, in a paper read before the *Société de l'Industrie Minérale*, recommends the greater use of the waste heat from coke ovens for the purpose of raising steam. He refers in this connection to the arrangements adopted at a battery of 100 Coppée ovens at Haveluy, the waste heat from which converts in twenty-four hours nearly 180 tons of water into steam of four atmospheres tension.

IV.—*LIQUID FUEL.*

Formation of Petroleum.—According to A. Veith,† Engler's researches show that petroleum is of animal origin. It is formed by the decomposition of marine animals, nitrogenous organic matters being decomposed with the evolution of ammonia, whilst the fats, under the influence of heat and pressure, yield glycerol and fatty acids; the first is washed away by water, and the latter is further broken up into hydrocarbons and water. The glycerol may also be changed into acrolein, and then into benzene. Gaseous hydrocarbons are formed by the reactions between carbon dioxide and the other hydrocarbons already formed.

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxv. p. 913.
† *Chemiker Zeitung*, vol. xiv. p. 1368.

H. Höfer* has long expressed the opinion that petroleum is of organic origin. To this the objection was raised that the oil is free from nitrogen, which it should have contained had it been derived from organic remains. Peckham afterwards discovered the existence of nitrogen in the petroleums of California, Texas, West Virginia, and Ohio, and gave his opinion in favour of the organic origin of these oils. He did not, however, find nitrogen to be present in the petroleum of Pennsylvania and New York, and he consequently expressed the opinion that this district, the most important of all the oil regions, owes its oil to the decomposition of vegetable matter. A consideration of all the circumstances of the case led the author, however, still to believe in the organic origin of this oil also. The nitrogen, if not present in the oil itself, might exist in the gases, also formed by the organic decomposition. This is very markedly the case in Pennsylvania, where the natural gas sometimes contains as much as 27·87 per cent. of nitrogen, and this nitrogen, the author has shown, cannot be derived from atmospheric admixture. The author gives analyses of natural gas from a number of places in proof of his theory.

The Sources of Petroleum.—In a lengthy paper on the sources of petroleum and natural gas, Mr. W. Topley gives a general survey of the geological conditions under which they occur in various parts of the world, and enumerates the conclusions to which geologists of the United States have been led as regards the vast areas with which they deal. Two theories of the origin of petroleum have been advanced. The first ascribes to it a purely chemical origin, and is drawn chiefly from the data of the Russian fields; the second is the organic theory of distillation from organic remains, and explains best the facts over the greater part of North America. The great pressure of gas and petroleum does not prove its deep-seated origin, but arises from the form of the stratification in the American fields. In Canada and the States the petroleum is usually found in anticlinals or interruptions to the dip in porous beds, such as sandstones and limestones. At the outcrop of these rocks the petroleum has disappeared, and its place is taken by water, which by its hydrostatic pressure causes the petroleum or gas to rise in the wells. This is readily seen in Indiana, according to Professor W. J. M'Cree, in the Cincinnati Arch, which is practically a dome some fifty miles across. Dr. T. Sterry Hunt, too, has shown

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 145–148.
† *Journal of the Society of Arts*, vol. xxxix pp. 421–437.

that oil was produced in beds near where it is found, that their porosity accounts for the stores in them, and that petroleum and gas mainly occur along anticlinal lines. When the strata are much disturbed, large stores of oil or gas are not likely to be found.

There is no uniformity in the geological ages of the strata which yield petroleum. Even in North America the age ranges from lower Silurian to Tertiary; both gas and oil also occur in the drifts. Rocks of secondary age, however, with the exception of the Cretaceous, are not oil-bearing in North America. In Europe, only small quantities occur in Palæozoic rocks. In Holland the range is from Trias to Cretaceous. In Eastern Europe it is mainly Tertiary, and wholly so in the Caucasus.

In other parts of the world the petroleum-bearing beds are, so far as is known, rarely of older date than upper secondary. Volcanic rocks occasionally contain pretroleum, but there is good reason to believe that these cases are generally impregnations into porous reservoirs of volcanic rocks from neighbouring sedimentary strata.

The author then proceeds to deal at length with the oil and gas deposits of the United States, Canada, and the Caucasus. Besides these countries, the following are mentioned as producers, and are more or less briefly described :—Mexico, Venezuela, Trinidad, Columbia, Peru, Argentine Republic, Egypt, Algeria, the Carpathians, Germany, Italy, France, Spain, India, Burmah, Japan, China, and New Zealand. As regards the United Kingdom, the author gives particulars of the various instances in which gas or oil has been found in small quantities. The production of petroleum in Derbyshire, in the three years 1886 to 1889, was 43, 66, and 35 tons respectively. In spite of the frequent occurrence of brine in borings, and the presence of fossiliferous strata, but very little oil has been found up to the present. This may be due to the frequent foldings aud contortions of the Palæozoic rocks, so that volatile matters have had every chance of escaping, though otherwise these rocks are most likely to contain oil. In many cases the brine may have replaced the escaped oil. The Sub-Wealden boring in Sussex was favourably placed for discovering petroleum, but none was found.

With regard to the duration of the supply, the author states that the recent diminution in the American supply is due to the restrictions imposed. If the records of each field be examined separately it is seen that the production has rapidly developed, and then slowly declined, in some cases, to zero.

The increased production is due to the discovery and development of new productive areas. This is especially the case with districts of high-pressure gas or oil, whereas low-pressure fields have longer lives. The chief exception to this rapid exhaustion of high-pressure areas is Baku; but even here there are said by some to be signs of exhaustion.

The history of all high-pressure wells is substantially the same; first, an enormous supply, and then signs of brine, followed by an increasing quantity, which finally spoils the well. To yield brine, with only a small proportion of oil, is the final stage of almost all high-pressure wells. It is true that a small supply of oil with much brine may continue for several years.

Such wells may pay in Germany, where there is a protective duty on imported petroleum, but they are at present worthless in highly productive areas. The time may, however, come when even the American oilmen will return to their now deserted "pools," and be content with the small production of old wells, now shut down and abandoned.

The comparative permanence of low-pressure areas is a hopeful sign for the future of petroleum. What is most wanted is a steady production, not subject to enormous variations in quantity, and consequently in price.

Petroleum in Russia.—In a review of the petroleum industry of Russia, M. B. Prilèjaïev* states that the production of naphtha is practically confined to the Caucasus, in the peninsula of Aspcheron, and principally in the vicinity of Baku. From 1821 to 1872 the production was a monopoly, and brought into the Treasury 87,000 roubles annually. In 1872 the monopoly was suppressed, and an excise duty imposed which brought in a total sum of 1,218,739 roubles between 1872 and 1877. This amount increased to 7,000,000 roubles in 1888, and 9,000,000 roubles in 1889. Between 1832 and 1862 the production varied between 255,500 and 358,300 pouds, but it rose to 1,685,229 pouds in 1869, from which date the enormous development dates. The approximate productions in 1875 was 6¼ million pouds; in 1880, 20¾ million pouds; in 1885, 115,000,000 pouds; and in 1889 it rose to 206,897,100 pouds (3,336,000 tons). The environs of Baku yielded about 99 per cent. of the Caucasian production. In the Baku fields there were 216 wells working in 1877, and 239 in 1888. In the Balak-

* *Economiste Russe*, through the *Journal of the Society of Arts*, vol. xxxix. pp. 275–277.

hani and Sabountchi fields there were 227 yielding wells in 1888. The average annual yield for each well was 776,794 pouds in 1888. The pipe system was inaugurated in 1877, and the amount delivered by it in Baku in 1888 was 186,220,476 pouds, whilst in 1890, up to November 1st, the amount was over 192,000,000 pouds. Most of the distilleries are in the Baku district, which contained 147 of them in 1889.

Besides in the Baku district, oil is produced in the environs of Tiflis, where there were 85 wells in 1887. Elisasetpol, Daghestan, Terek, and Kouban are other producing districts. Particulars are given of the distribution of the refineries in Russia, and of the carriage of the petroleum. The exports in 1889 of illuminating oils to the following countries are shown in millions of pouds:—United Kingdom, 6; Austria, 4; Germany, 3; Italy, 2; Belgium, 2; Turkey, 7; East Indies, 5; China, 1; Persia and Japan, ½ each; and smaller quantities to other countries.

Petroleum in Lower Alsace.—Although petroleum has been known for centuries to exist in the vicinity of Pechelbronn in Lower Alsace, it is only recently that its great value has been appreciated. The oligocene rocks through the whole of the plateau of the Upper Rhine contain deposits of asphalt and petroleum, and the productive area has been proved, by boreholes recently put down, to extend over 154 square miles. The oil was originally obtained by mining in the bituminous sandstones at Pechelbronn, this operation having gone on without interruption from 1743 to the end of 1870. Since Alsace formed part of the German empire, the oil has been successfully obtained by means of deep boreholes, and since 1888 mining the sandstone has been completely abandoned. The production of oil from the Pechelbronn mine, which in 1871 amounted to only 128 tons, increased gradually to 1805 tons in 1879, and since then has rapidly risen to 8692 tons in 1888. In a book recently written on the resources of this district, Dr. Jasper gives an historical account of the industry, a sketch of the geology of the district, and a description of the methods of deep boring now in vogue. The book is illustrated by a map of the district on the scale of 1 to 80,000, in which the concessions and the various boreholes are well shown.*

Petroleum in Japan.—Mr. J. Adachi † gives an interesting statement relative to the production of petroleum in Japan. The rocks of

* *Das Vorkommen von Erdöl im Unterelsass.* Strassburg, 1890.

† *Mineral Resources of the United States*, Washington, 1890, pp. 474–478.

the oil region are undoubtedly of Tertiary age. The oil-bearing rocks at Kusodsu, in Echigo, consist of soft greenish-grey shales and grey fine-grained sandstones. There are no flowing wells in the Japanese oil regions. The oil is never pumped, but is raised out of the well by buckets. These buckets are attached to a rope, which passes over a wheel at the surface, and while one bucket is coming up the other is going down. In this way the weight of the empty bucket helps the one man who does the hoisting. The average bucket contains five gallons.

A well in Japan 300 feet deep would cost £60, and would be completed in three months.

Oil Shale from Brazil.—Mr. G. Valentine* describes a carbonaceous mineral or oil shale from Brazil, and discusses its formation and composition as a key to the origin of petroleum. Around the coast, over large tracts of shallow water, there are large growths of mangrove trees. The wood is attacked by animal life, and is rapidly disintegrated. Part of the woody matter is carried away in solution in the water, whilst other parts are removed in suspension and deposited among the roots. This deposited vegetable mud is the origin of a carbonaceous and bituminous mineral called "tufa," which will generally float on water. An average assay shows :—

Volatile Matter.			Coke.		
Gas,	Water at 212° F.	Sulphur.	Fixed Carbon.	Sulphur.	Ash.
57·03	4·57	0·04	7·84	0·82	29·70

At low temperatures, the mineral yields 65·5 gallons of oil per ton. A section of the strata on the island of Joas Branca, sixty miles from Bahia, shows 15 feet of sand, 9 feet of clay, and then an undetermined thickness of tufa, 30 feet having been worked. The author then deals with the part played by animal and insect life in disintegrating vegetable matter, and mentions the means by which organic matter may be stored up in the earth. These are: the burial of trees, &c.; the infiltration of vegetable matter, disintegrated by various organisms, into the earth; the washing down into the sea of these deposited matters; and their deposition. Not only is the suspended organic material deposited, but the organic matter in solution is decomposed by mineral salts in sea water and is precipitated.

The author sees in these deposits a means of explaining the genera-

* *Proceedings of the South Wales Institute of Engineers*, vol. xvii. pp. 20–28, two plates.

tion of petroleum. If a considerable bed of this tufa or like material were covered by other strata, such as sand, as in this case and in the Pennsylvania deposits, it might be subjected to such a temperature and pressure as would cause a rearrangement of the chemical constituents, producing a solid, liquid, or gaseous product. These products might be absorbed by the surrounding strata, or might find their way to the surface. A porous bed of sandstone would absorb the oil or gas, and form a reservoir from which they might be tapped by a borehole. The flow of gas or oil would continue while the temperature and supply of shale were maintained. As the oil was relieved of pressure, so would its density increase since the volatile constituents would escape most readily. This would account for the heavy oils found near the surface.

Storage of Petroleum.—Mr. W. T. H. Carrington * describes the appliances necessary for dealing with petroleum in bulk and the methods of using them. The mains forming the pipe lines are from 6 to 8 inches in diameter, and are usually of wrought iron. A flexible tube of canvas or other material is used for making connection with the steamer. The petroleum is passed through a dirt tank into the storage tanks by pipes entering at the sides or bottom. The suction and delivery pipes should preferably be kept independent. The author deals with the size of the tanks and their construction, special attention being given to the foundations. In hot climates the top of the tank is covered with water. The bottom of the tank should be placed so that it can be inspected. Petroleum can be withdrawn from the tanks by gravity or by power when it is barrelled. A description of the method of barrelling is also given.

Cost of Boring Petroleum Wells.—In the United States the price per foot for boring wells is agreed upon from time to time between the Producers' Association and the Oil Well Drillers' Union. The prices recently agreed upon vary from 2s. to 2s. 6d. per foot in most of the counties of Pennsylvania. In Ninevah the price amounts to 8s. per foot. When five or more wells can be secured in the same immediate vicinity, a reduction of 2½d. per foot may be made.†

Ozokerite in Galicia.—S. Deutsch ‡ describes the occurrence of ozokerite at Boryslaw-Wolanka, in Galicia. This is the largest known

* Paper read before the Institution of Civil Engineers, March 24, 1891.

† *Mineral Resources of the United States*, Washington, 1890, p. 467.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 25-30, with plate.

deposit of ozokerite. The zone in which the ozokerite is found is rather more than 1500 yards in length, and has a mean width of some 300 yards, with a total area of 104 acres. Petroleum, however, accompanies the ozokerite, and the area over which this is found, and which includes that of the ozokerite, is 222 acres. The ozokerite has a specific gravity varying from 0·845 to 0·930, and on heating to temperatures varying with different samples between 52° C. and 85° C. it melts, and becomes a clear oily liquid. It is variously coloured. Organic analysis shows it to belong to the C_nH_{2n} hydrocarbons, and to consist theoretically of 85·71 per cent. of carbon and 14·29 per cent. of hydrogen. On being subjected to a distillation process, it yields about 4 per cent. of benzene, 27 per cent. of petroleum, 7 per cent. of lubricating oil, 52 to 57 per cent. of paraffin, 4 per cent. of coke, and some gas.

Technically its value consists in its yielding a substitute for beeswax, termed ceresin, and paraffin, the former being amorphous, whilst the latter shows a crystalline structure.

The ozokerite occurs in beds of Miocene age, which adjoin the Oligocene rocks forming the edge of the Carpathian Mountains. The Miocene formation consists mainly of clay slate and sandstone; it contains but little limestone and much gypsum and salt, covered with a bed of plastic clay. The ozokerite occurs in veins and masses.

V.—*NATURAL GAS.*

Analyses of Natural Gas.—H. Höfer * gives a large number of analyses of natural gas, collated from various sources. The following are some of those given :—

Origin.	CH_4.	N.	H.	C_2H_4.	O.	CO_2.	CO.	H_2S.
Ohio	93·35	3·41	1·64	0·35	0·39	0·25	0·41	0·20
Indiana . . .	92·67	3·53	2·35	0·25	0·35	0·25	0·45	0·15
Indiana . . .	94·16	2·80	1·42	0·30	0·30	0·29	0·55	0·18
Italy	94·82	3·13	...	...	...	2·05	...	...
Italy	89·42	4·61	...	...	...	5·97	...	...
Italy	98·85	0·41	...	...	...	0·74	...	...
Italy	98·93	0·59	...	...	...	0·48	...	...
Italy	80·60	0·39	...	...	...	1·14	...	...

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 146–147.

Ethylene iodide, which occurs in such large quantity (17·87 per cent.) in the last of the examples given, that of gas from Torrente Sillaro, in the province of Bologna, has never before been observed in any sample of natural gas.

Discovery of Natural Gas at Pittsburgh.—A recent borehole has proved that the town of Pittsburgh is underlain by the gas-producing sand from which the gas-wells of Washington County, Pennsylvania, draw their supply. This is known as the "fifth sand," and has now been struck at Pittsburgh at a depth of 1990 feet. At 680 feet a seam of coal 8 feet in thickness was met with. The well is producing about 550,000 cubic feet of gas a day, equivalent to about 25 tons of coal.*

Pumping Natural Gas.—Gas is now being pumped near Pittsburgh from wells which, as far as pressure is concerned, had become exhausted. The experiments have shown that the gas can be pumped long distances through pipes of a size much smaller than those now in use.†

VI.—*ARTIFICIAL GAS.*

Gas Furnaces.—Mr. B. Dawson ‡ points out that it is sometimes a distinct advantage to employ gas for heating furnaces in which the saving in cost of fuel is itself a secondary or comparatively unimportant matter, but that the exact point at which it is advantageous to dispense with the somewhat costly system of reversing regenerative chambers is one on which there is some diversity of opinion. The use of gas with cold air is necessarily wasteful, owing to the inability to recover the waste heat from the flame or products of combustion before they pass away to the chimney; and this waste may be prevented by the employment of what may be termed continuous, as opposed to reversing, regeneration.

The author then proceeds to divide gas furnaces into four classes:—

(*a.*) Furnaces with reversing regeneration are of several different kinds:—1. The ordinary Siemens furnace, in which both gas and air are heated before admission to the interior of the furnace, by regenera-

* *Iron Age*, vol. xlvii. p. 1089. † *Ibid.*, vol. xlvi. p. 1048.

‡ *Transactions of the Institution of Mechanical Engineers*, 1891, pp. 47-93, twenty-four plates.

tive chambers. 2. The Batho or Hilton furnace, in which the regenerative chambers, instead of being partly or entirely underground, are encased in cylindrical wrought-iron vessels erected upon the ground level. 3. Furnaces in which the air only is regenerated by being passed through chambers, the gas being admitted direct from the flues by which it arrives from the producers. In these furnaces the whole of the escaping gases or waste heat has to pass through one of the two air-chambers on its way to the chimney. 4. The furnace recently described by Mr. Head,* in which a portion of the waste heat is taken back to the gas producer. 5. The various regenerative blast-furnace stoves of the Cowper, Whitwell, and other kinds. These, however, are not considered as gas furnaces, and are therefore not further referred to.

(*b.*) In furnaces with continuous regeneration the air, before admission to the interior of the furnace, is heated in flues or pipes by radiation or conduction from the bottom of the furnace, and through thin walls which separate the air-flues from the flues that carry the spent gases or waste heat to the chimney.

(*c.*) In non-regenerative furnaces the air is admitted to the interior of the furnace at its natural or atmospheric temperature.

(*d.*) Blowpipe or forced-blast furnaces are of two kinds:—firstly, those in which the air is supplied at its natural or atmospheric temperature by a fan or blower; secondly, those in which the air so supplied is heated by the spent gases or waste heat from the furnace, by being passed either through coils or stacks of pipes, or else through brick tubes or flues, as in the case of the Radcliffe furnace and others.

A large number of examples of each class are illustrated. Steel-melting furnaces fall under the first class. Continuous regenerative furnaces are used mostly for annealing, and non-regenerative furnaces are used for calcining and roasting ores and for reheating furnaces. Blowpipe furnaces have been used for puddling, but the author believes that this type has not had any great success.

The failure of many non-regenerative gas furnaces may often be attributed to the difficulty in mixing the cold air and the hot gas, and to the regulation of the chimney draught. The air and gas should be introduced in a number of small streams, or should be partially ignited in a preliminary combustion chamber.

After dealing with the present scanty application of reversing regenerators to crucible steel melting, the author mentions the various forms of reversing valves employed. The objections to the employment of

* *Journal of the Iron and Steel Institute*, 1889, No. II., p. 256.

reversing regenerators with reheating furnaces are met by the advantages of a central fuel-producing station. In many cases the producer may be combined with the furnace, and part of the waste heat from the furnace may be used to heat the air for the producer. At the present time furnaces with reversing regeneration for heating tubes are only employed in the largest works. Besides the use of gas-fired furnaces in the iron and steel industry, many other applications are described by the author.

VII.—*COAL-MINING.*

Coal-Mining in 1850 and 1890.—Mr. J. Tonge * reviews the progress in coal-mining, and compares the state of the industry at the present time and that of 1850, when legislation first dealt with its difficulties. The output has increased from 50,000,000 to 185,000,000 tons, persons employed from 216,217 to 563,735, while accidents causing deaths have decreased from 4·56 to 1·88 per thousand. These changes are clearly set out in a diagram. A slight review of legislation and inspection is given, and the author then turns to improvements in plant. Shafts have been lined, and conductors and safety cages introduced, engines have been improved, and hauling arrangements evolved from the most meagre devices. Lighting, ventilating, and explosives have been bettered in all ways. The output per man has increased from 21 to 24 cwts. per day, owing to the increased facilities, in spite of the shorter hours and of all the other operations performed, such as picking and cleaning the coal.

Mining at Great Depths.—The question of working coal at depths from 2000 to 4000 feet was investigated by the Royal Commission of 1869, but since then, according to Mr. W. E. Garforth,† some three thousand million tons of coal have been raised, and the depth of workings have been increased from 2376 feet up to 3120 feet. Discoveries in connection with colliery appliances, especially in electrical work and increased knowledge in methods of working coal, have produced a feeling that coal may be worked at much greater depths than at present. At the same time there are many difficulties in the way. At Ashton Moss Colliery the increase of temperature is one

* *Transactions of the Manchester Geological Society*, vol. xxi. pp. 180–194, one plate.
† *Ibid.*, vol. xxi.

degree for every 75 feet, but there are reasons for believing that the increase has a diminishing ratio. In the six-foot seam in this colliery, at a depth of 3120 feet, the temperature is 87° F., and the air in the roadways and at the face is dry, and not surcharged with moisture, as had been predicted. The men work for the same hours, but not with the same energy and vigour as in shallower pits. No water is met with, and not more gas than in other mines. The quality of the coal is as good as, or even superior to, that of coal found at less depths. The author makes a number of suggestions for working deep mines. He is of opinion that coal ought to be won without greater loss than in the past, and he believes that coal will be worked at as great depths as it can be proved to exist.

Coal-Mining in China.—An interesting account is given, by Mr. C. W. Kinder,* of the railways and collieries in North China, and of the difficulties experienced with the natives. A borehole put down at Tongsan, eighty miles north-east of Tientsin, in 1878, discovered coal of excellent quality. The best spot for a colliery was Linn, fifteen miles further east, where shaft sinking was commenced in 1888. Communication with the river was made by canals and a light tramway, as there was so much opposition to a railway. Two shafts of 300 and 600 feet lined with limestone blocks were sunk. The coal-bearing stratum is 800 feet thick, and dips 40° to 50°. It contains thirteen seams, nine of which are worked, having a total thickness of 125 feet. Only two are of good quality—one 30 inches, the other 70 inches thick. The latter contains 4·54 per cent. of ash, and 0·97 per cent. of sulphur. On account of high dip, the workings are laid out on the Belgian system. The coal is cut overhand, and the gob is packed with stuff from the surface. Special systems are used in the thick seams, and in thin seams a longwall system is used. The pumping plant consists of two 20-inch lifting sets and two 20-inch plunger pumps, worked by two differential engines with cylinders 50 and 30 inches, and a stroke of 6 feet. A Guibal fan, 30 by 10 feet, with a Walker shutter, driven by a compound engine, passes a large amount of air, owing to the large airways and numerous splits. The output has increased from 3613 tons in 1881 to 241,136 tons in 1888, and 247,867 tons in 1889.

Fire-clay of excellent quality is found in the district, and the coal from No. 5 seam is used for gas making. The iron ore of the district

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. ciii., pp, 278–306.

is rich in silica, and cannot be profitably smelted. The average pay of miners on day work is 7d., but twice this amount is earned on the "butty" system. Unskilled labour is cheaper, and skilled labour dearer, than in Europe.

Mr. J. Stevens * gives further particulars of the Kaiping Coal Mines, about eighty miles north of Tientsin, where coal-mining has been carried on for some ten years on a comparatively large scale. The shafts are 600 feet deep and 14 feet diameter, lined with dressed stone and cement concrete, and from the level to which the shafts are sunk there are inclined planes 500 feet long, worked by steam-power, and dipping at an angle of 50°. These work the coal to the dip of the shaft. There are fourteen seams of coal ranging from 1 foot 3 inches to 35 feet thick. Some of the seams are of fairly good quality, and one seam of 5 feet 6 inches thick is of excellent quality, and is the one chiefly worked. In the mine there are some thousands of yards of steel wire rope at work, and also some sixty ponies, and many of the main roads at the pit bottom are arched in the best possible way. The daily output has reached over 1200 tons per day, but about 1000 tons can be taken as a fair average output. The colliery is equipped with the most modern English machinery, the largest winding-engine being a coupled horizontal high-pressure engine, with cylinders 28 inches diameter by 4 feet stroke, and the drum 17 feet in diameter. The cages are double-decked, and carry four tubs each. The rate of winding will compare favourably with that at the best collieries at home. The mine is ventilated by a Guibal fan 30 feet diameter, and the pumps are two of Davey's compound differential pumping engines. The headgear is entirely girder work, and the heapstead is all well laid out, with large screens and a complete system for picking dirt out of the coal as it leaves the screens. There are ten Lancashire boilers, ranging from 5 feet 4 inches to 8 feet in diameter, and from 16 feet to 30 long; also five vertical boilers, 6 feet in diameter. There are workshops and foundry fitted with best English tools, and all ordinary engineering work is carried out there, including the building of engines and boilers complete. There are over ninety coke ovens, and also machinery for the manufacture of patent fuel. The brickworks are extensive, and are equipped with English machinery. The surface is well laid out with ample sidings. All the coal trucks are of 10 tons capacity each, and the gauge of road is 4 feet 8½ inches. The coal trucks are run direct from the heapstead screens to the shipping

* *Colliery Guardian*, vol. lxi. p. 658.

wharves and other points, distant from fifty to ninety miles from the colliery.

Diamond Boring at Newton Colliery.—Some notes on a diamond bore put down at Newton Colliery, Lanarkshire, during 1889–90, are given by Mr. T. Arnott.* A portable plant was used, the engines, boiler, and pumps being mounted on a carriage, and weighing about 5 tons. Sixteen gallons of water per minute were required to keep the bore clear. A triangle 38 feet high was used; the rods were 12 feet long, weighing 50 lbs. Weights were arranged so that the working pressure on the diamonds was 15 to 20 cwt. when cutting soft strata or coarse sandstone, and 20 to 30 cwt. when cutting hard rock. A leader and two assistants, working nine-hour shifts, were employed, and in sixty-seven working days the bore was sunk to a depth of 149 fathoms. In good strata the speed was 100 revolutions per minute, and hard rock was bored quickest, as much as 42 feet being cut in one shift, at a depth of 30 fathoms. After passing through troubled strata, the Glasgow upper coal was proved to be 3 feet 1 inch thick at a depth of 123½ fathoms.

Electric Power Diamond Drill.—M. Georgi † describes, with the aid of several illustrations, the application of electricity as motive-power in the case of a diamond drill. The cost of such a boring plant, with engine and dynamos for three drills, is placed at £625. The arrangement is said to possess the advantages of simplicity and low working cost.

Boring-Machine with Emery Crown.—Of late years, for deep borings in hard rocks, the diamond boring-machine has been largely employed. The great cost of this method of boring has been obviated by O. Terp,‡ who replaces the diamond crown by one of emery, which is made to rotate at three to four times the speed. The upper portion of the borer consists of a hollow cylinder of soft metal with a core extractor inside, whilst the boring surface is made of a solid mass of emery. With this machine boreholes as much as 39 inches in diameter may be put down, whilst holes ¾ inch in diameter for blasting can also be made.

* *Transactions of the Mining Institute of Scotland*, vol. xii. pp. 154–159.
† *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 95.
‡ *Berg- und Hüttenmännische Zeitung*, vol. xlix. pp. 415–416.

The Trouvé Erygmatoscope.—According to Mr. G. A. André,* M. Trouvé's erygmatoscope is about to be used in a boring for coal in the Boulonnais district, now being explored. This instrument consists of a very powerful electric glow lamp, enclosed in a metal cylinder. One of the two hemi-cylindrical surfaces constitutes a reflector; the other is of thick glass, over against the point of light. The bottom of the cylinder, inclined at an angle of 45 degrees, is an elliptical mirror, and the top is open to permit of observations being made. Observations are made from surface through a telescope, the lamp being so mounted that its rays are intercepted in the upward direction. The whole of the apparatus is suspended in the borehole from a cable composed of two insulated conducting wires, which may be wound on a reel. The electric current is obtained from a portable battery specially designed for the purpose by M. Trouvé. It is said that at a depth of 300 yards a seam of coal or rock stratum may be minutely examined. This instrument is likely to be of great service in prospecting operations. This apparatus is also illustrated in *Le Génie Civil*,† where it is stated that the Portuguese expedition to Mozambique for exploring for minerals and coal is provided with this apparatus. By increasing the power of the lamp or telescope, greater depths can be explored.

Preservation of Mine Timber.—Experiments made at the Altenwald Colliery, Saarbrücken, of coating mine timber with lime, coal tar, wood tar, and carbolineum, proved that lime was the worst and carbolineum the best preventative against dry-rot. The cost of a double coating of carbolineum to a prop of 8¼ feet in length and 10 inches in diameter was 6d. for the carbolineum and 1¾d. for labour.‡

At various mines in Saxony not only are the supports wetted occasionally to prevent dry-rot, but the wood is first impregnated with a solution of ferrous sulphate before being put into use. This method of treatment has been adopted for some time, and has been found to give very good results.§

Mine Timber Framing Machine.—An illustration is given in the *Engineering and Mining Journal* ‖ of a machine designed for framing timber for use in mines. It has ten saws, five at each side, so that both

* *The Colliery Guardian*, vol. lxi. p. 657.

† Vol. xvii. p. 271.

‡ *Berg- und Hüttenmännische Zeitung*, vol. l. p. 85.

§ *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 108.

‖ Vol. li. p. 287.

ends are cut at the same time. All the saws are adjustable in every way. The log to be cut is secured on a carriage by dogs and passed through the machine, which cuts out the ends to the desired form. Timbers up to 10 feet in length and 16 inches in diameter can be cut. A smaller size of machine, with revolving carriage and fewer saws, is used for small timbers.

Economy of an Electric Mining Plant.—After briefly describing the Hercules mining machine, Mr. C. F. Scott * draws a comparison between hand labour and machine labour for coal-mining. In machine mining the stalls can be made much wider because of the greater rapidity of mining, so that the roof will stand a shorter time with fewer pillars. The immediate effect of the introduction of coal-cutting machinery is to reduce the cost of undercutting from 20d. to 5d. per ton of 1½-inch coal in the Pennsylvania district. Taking into account the other expenses, there is a saving of 25 per cent. Another advantage of machine mining is that perfect pillars are left, and can be recovered, as there is no temptation to rob them. The reduction of the number of stalls for the same output, due to machinery, also causes a great saving in the timber, the number of roads, and the tramways that have to be kept up. The saving in coal, due to the introduction of machinery, is also very great; this arises from the small amount of slack and the larger coal produced by the smaller height and greater depth of undercutting, and also from the pillars not being crushed. An estimate is given of the saving in expense by using a plant of seven machines, run ten hours a day, and cutting 233 tons. The cost is £29, 11s. 3d., made up as follows:—Fuel, 9s. 7d.; wages, £2, 10s.; deterioration of boiler, engine, electrical apparatus, and wire, £1, 6s.; cost of repairs, £1, 0s. 8d.; cost of working, £4, 17s.; loading and blasting, £19, 8s. The indirect saving is estimated at £2, 19s. The cost of hand mining is £38, 6s. 8d. The saving by the use of machines is therefore considerable in all directions.

Firing Shots in Fiery Mines.—M. Tauzin † describes the fire-syringe (*briquet pneumatique*) of Bourdoncle for igniting the fuse when firing shots in fiery mines. The fuse is held by a rubber washer, which is caused to grip it when the cylinder is screwed down. An air-tight

* Paper read before the Engineers' Society of Western Pennsylvania, through the *Colliery Guardian*, vol. lxi. pp. 540–541.

† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1891, pp. 1–7, one plate.

piston works in this cylinder, and is forced down by a rapid blow so as to compress the air and thereby ignite the fuse. The cylinder can then be unscrewed so as to release the fuse after the first sparking is over. An attachment to the base of this device allows it to be placed on the ground while the piston is being forced down. This device has been adopted in several mines with success.

At the Concordia Colliery at Oelsnitz, in Saxony, blasting has only recently been introduced in winning the coal. The dynamite cartridges are surrounded by water, only one shot is fired at a time, and that only after taking the precaution to lay the dust with water to a distance of 33 feet from the hole before firing.*

Safety Fuse and Lighter.—According to Mr. J. Grundy,† though safety fuse may be more convenient under certain circumstances, it is difficult to see why electric shot-firing is not more generally used. The author gives a description of Bickford's colliery fuse, safety lighters, and nippers. The lighters consist of a thin tin tube about 2½ inches long by ¼ inch in diameter. It is open at one end to allow the fuse to be inserted to a depth of 1¼ inch, and holds a small glass bulb containing acid; this is broken by the nippers, so as to allow the acid to come into contact with some substance which causes the ignition of the fuse. The essential factors for their use are that they should be kept dry, that the end of the fuse is in good condition, and that suitable nippers are used and applied in the right position, namely, at the end of the igniter. This system of shot-firing is much preferable to the use of a wire heated in a safety lamp.

Firing Shots by Electricity.—In sinking a shaft at the Liebe Gottes Mine at Zbeschau, near Rossitz, in Moravia, a premature explosion occurred on the workmen ascertaining before firing, according to requirement, the length of the spark given by the firing machine (Nobel system).‡ It is believed that one of the wires connected with the blasting charge must have touched the leather of his sleeve, and thus have produced contact. In connection with the inquiry which was instituted to ascertain the cause of the explosion, five shots were fired at the surface with the same machine. In each case the blasting charge was only connected with the firing machine by a single wire. The wire was allowed to rest on the non-conducting indiarubber

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 118.

† *Transactions of the Manchester Geological Society*, vol. xxi. pp. 143–154.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 485.

edge of the machine, the second pole of which was not brought into contact with the earth. Of these five shots no less than three exploded, while the other two did not. The return current passed of course through the earth; but as there was no contact with the other pole of the machine, the current, however, could not pass to the isolated pole of the machine, and the spark leapt from the metal casing across the indiarubber edge of the machine, a distance of about one centimetre, direct to the circuit wire. The possibility of such an occurrence is rarely thought of, and, in view of the danger, more than ordinary care should evidently be taken with the firing arrangements.

Electric firing is now being largely employed in the mines of the Freiberg district, Saxony. At the Himmelsfürst Mine it was found in using kieselguhr dynamite that a portion of the blasting charge sometimes failed to explode. This has now been replaced by gelatine dynamite, and not a single instance of this partial failure to explode has since been observed.*

Use of Explosives in Mines.—Mr. J. Ford,† in dealing with the use of explosives in mines and the law in relation to shot-firing, describes tonite, carbonite, roburite, and securite. He regards tonite as the most powerful, and carbonite as the safest in fiery mines. The use of fire-extinguishing cases or compounds is recommended. The law in regard to shot-firing is very defective. Electric means of firing should be made compulsory, and a definite time should be allowed before a miss-fire may be approached. The advantages of electrical firing are that there can be no hanging fire, and the explosive can be ignited at the bottom of the hole. A number of rules for shot-firing are proposed. These are to the effect that electrical firing only shall be used, simultaneous firing of several shots, use of water cartridges or equivalents, and all shots to be fired at night. The author is of opinion that the expansion of carbonic acid might be used instead of explosives, and cites the Giffard gun in support of his contention.

Experiments with Explosives.—Mr. M. W. Brown ‡ describes a series of experiments on explosives carried out by him at the Cymmer Collieries in August 1890. The explosives were placed in a cannon fitted in a boiler, partly built in with masonry. The bore of the cannon

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 104.

† Paper read before the National Association of Colliery Managers, Dec. 6, 1890.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 49–61, one plate.

was 2 inches in diameter and 20 inches deep, and the boiler was about 6 by 18 feet. Gas from a blower was introduced to make an explosive mixture, containing ten per cent. of gas and charged with coal dust. All the explosives were fired without any stemming. The explosives used were ammonite, bellite, blasting gelatine, carbonite, compressed blasting powder, roburite, securite Nos. 1 and 2, and tonite. The explosives were supplied from the neighbouring collieries, where they were in ordinary use. Details of the experiments are given in a tabular form. They show that none of these explosives are flameless, and that all will ignite explosive mixtures of gas and air, charged with coal dust, when fired unstemmed. In a second series of experiments, some of the explosions did not ignite the gas, and this might be due to the fact that the gas was apparently not thoroughly mixed with the air. Strong detonators, it was shown, are capable of igniting gas. The author concludes that although all these explosives are dangerous when unstemmed, yet several of them may possess some degree of safety when fired under the usual conditions.

Mr. H. Walters * gives an account of his experience with explosives during eight years in a Silkstone mine, in which gas sometimes occurred. The dust present in the mine and the blowers of gas precluded the use of gunpowder. The author was, therefore, induced to make a series of experiments with various explosives. Gelatine-dynamite, and gelignite were not altogether flameless, and roburite, in its early days at least, was unsatisfactory for several reasons. Gelignite had been adopted, and there had been no trouble with it. No explosive in use at present would appear to be absolutely flameless; the more nearly flameless the explosive is, the greater the power of the detonator required. The friction due to the explosion is likely to generate considerable heat, and this may in some cases be the cause of ignition of firedamp. The danger of the detonator does not appear to have been considered. Gunpowder is to be preferred for the getting of coal, and much might be done to improve its quality and to reduce the flame from it, so that it could be used with greater safety. Higher explosives are often quite as safe to handle as powder, however, and can be used where powder cannot be employed. Finally, the author expresses the opinion that there are prospects of producing a safe and desirable explosive.

Messrs. M. Walton Brown and W. Foggin † describe a series of

* *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 31–34.
† *Ibid.*, vol. ii. pp. 85–91.

experiments with carbonite recently made at the North Biddick Collieries. The experiments in question were made to supplement those made at Cymmer Collieries in August last, and were carried out under similar conditions. After giving particulars of each shot fired, the authors state that the experiments are at variance with the results of those made in Germany and at Cymmer, but confirm the opinion of the French Commission, viz., that the explosives which can best be recommended, as regards safety, are dual mixtures, such as octonitric cotton, mononitro-naphthalene, dinitro-benzol, and naphthalene, with ammonium nitrate or other substances. In the case of mixtures of dynamite with ammonium nitrate or other bodies, the unconfined detonation appears to be irregular as regards the phenomena of the ignition of the explosive mixture. It seems probable that these irregularities may be due to the difficulty of obtaining perfection of mixtures of the substances.

Mr. W. Stewart * has used carbonite in all blasting operations underground for nearly twelve months, and finds that the experiments made in Germany with this explosive are fully verified. The author states that he had used over a ton of carbonite in driving hard headings, ripping rock top, &c., and in no single instance had a trace or spark of flame been seen. Carbonite, which is of a plastic nature, and supplied in cartridges, is perfectly safe to handle, and will not explode when struck with a hammer or stone. Even in a frozen state it is far less susceptible to shock than dynamite. Owing to its great chemical stability, carbonite can be stored with perfect safety for any length of time without losing its original power or other characteristics. It can only be exploded by a detonator, like other high explosives, and not by merely being brought into contact with a flame. Carbonite thus represents an intermediary between gunpowder and dynamite, combining as much as possible the advantages of both.

A number of experiments with roburite were carried out at Guéret's Grasgola Colliery in the Swansea district. The shots were fired by electricity and by a fuse. The fumes were but slight, and the work done was satisfactory. No flame was seen.†

M. Larmoyeux ‡ gives the results of experiments with *antigrisou Favier* and grisoutite at the Marchienne Colliery in September 1890. The antigrisou Favier consists of a mixture of 10 per cent. of ammonium

* *Proceedings of the South Wales Institute of Engineers*, vol. xvii. pp. 61-66.

† *The Colliery Guardian*, vol. lxi. p. 320.

‡ Association of the Engineers of the Liége School of Mines (Mons section), 19th September 1890; *The Colliery Guardian*, vol. lxi. p. 709.

chloride with Favier powder, which is composed of 12 per cent. of dinitro-napthalene, and 88 per cent. of ammonium nitrate. The admixture of ammonium chloride renders the powder less deliquescent, and also renders it safer when exploded in presence of fire-damp and coal-dust. Experiments performed to determine its relative strength as compared with grisoutite, by firing in a mortar and in expanding a lead block, showed that it was as two to one. The antigrisou did not ignite gas, but there was explosion when grisoutite was used in several cases. No flame was seen, and the presence of a short tamping seemed to render the explosive secure.

Experiments made with fire-damp dynamite, in charges varying from 0·243 lb. to 0·661 lb., showed that in no case was coal-dust exploded, but that charges of from 0·33 lb. to 0·44 lb. frequently exploded mixtures of dust and fire-damp containing 5 per cent. of CH_4, and did so regularly when the percentage of gas reached 6. Five per cent. of the gas, even without dust, gave rise to a slight explosion with a charge of 0·33 lb. of the explosive, but with a charge of 0·22 lb. no explosion resulted when less than 9 per cent. of CH_4 was present. The coal used in the experiments was the gas coal of the Rossitz district, Austria.

Other experiments made with this explosive in Belgium and elsewhere gave much better results as regards freedom from explosions.*

Experiments have been made in Saxony with bellite and lithotrite in blasting hard rock. The results were, however, not satisfactory, though of the two the last-mentioned explosive was apparently the better.†

Wire Ropeways.—An aerial wire ropeway for the conveyance of coal across the Youghiogheny River, near Connellsville, is illustrated in the *Engineering and Mining Journal.*‡ Two cables, each 2 inches in diameter, are used across a span of 1000 feet. They are close together at the receiving end and 30 feet apart at the discharging end. An endless steel haulage rope, ⅝ inch diameter, is employed. The buckets are two in number, each of 2½ tons capacity, 4 feet in diameter, and 6 feet deep; they have hinged counterweighted bottoms, and discharge and close themselves automatically. The tower on the receiving end is 40 feet higher than the other, so that the buckets run down the incline by gravity. Each trip takes 30 seconds; the capacity is estimated at 750 tons per ten hours.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 74.

† *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 104.

‡ Vol. li. p. 374.

A wire ropeway $1\frac{3}{4}$ mile in length has recently been made by the Trenton Iron Company of New Jersey. The standing cable is $1\frac{3}{8}$ inch diameter on the loaded side and 1 inch on the empty side. The traction cable is of $\frac{3}{4}$ inch diameter, and is of crucible steel, 6 strands with 12 wires to a strand and a hemp core. At intervals of 135 feet lugs are placed $1\frac{1}{8}$ inch in diameter and 2 inches long. The hemp core of the cable is cut and a copper pin driven through the lug and cable, and the inner chamber of the lug filled with babbitt metal. The breaking strain of the traction cable is 21,000 lbs., giving a factor of safety of five. There are 133 buckets each of 5 cubic feet or 700 lbs. capacity. The carrying capacity of the tramway is about 400 tons a day.*

Electric Haulage.—An electric haulage plant, installed last year in the Mines de Marles, has given such satisfaction that it is to be enlarged. The generator is a 26-unit Edison machine, giving 400 volts at 900 revolutions. The pit is nearly 1000 feet deep, and the line runs along a gallery $1\frac{1}{4}$ mile in length. The locomotive is 7 feet 3 inches long, 2 feet 4 inches broad, 4 feet 11 inches high, and weighs 2 tons 6 cwt. The motor is a 10-unit machine, and drives both axles by screw gearing. A speed of over nine miles per hour is developed with an expenditure of 10-horse power when hauling twenty-five loaded skips, each weighing 14 cwt. The conductors are flange rails on porcelain insulators. The efficiency is stated to be 75 per cent.†

Mr. J. Clarke proposes to fit up electric plant to haul 100 tons a day on a road 600 yards long, against a gradient of 1 in 91. Before doing so he made inquiries, and has given the results in several cases of American installations. From the discussion it appears that it is intended to put down several electrical installations in Scotland.‡

Mining Locomotive.—A mining locomotive, for use with an overhead conductor, is illustrated in the *Engineering and Mining Journal.*§ The operating devices are placed at one end, and the machine is built low, so that the driver has a clear view in either direction. Lamps with parabolic reflectors are placed at each end.

Iron and Steel Wire Ropes.—Mr. A. H. Stokes‖ divides wire

* *Iron Age*, vol. xlvii. p. 757. † *The Electrician*, vol. xxvi. p. 659.

‡ Paper read before the National Association of Colliery Managers, Nov. 20, 1890, through *The Colliery Manager*, vol. vii. pp. 237–238. § Vol. li. p. 171.

‖ Paper read before the Derby Society of Engineers, through *Industries*, vol. x. p. 302.

ropes into three classes, according to the material from which they are made—namely, iron, mild steel, and plough steel. The average breaking load of iron wire ropes is 20 tons; of steel, 35 tons; and of plough steel, 50 tons per square inch of sectional area. The safe working load for iron wire ropes is 2 tons; for steel, 3½ tons; and for wire ropes of plough steel, 5 tons per square inch. The increasing depths of our coal mines compel the introduction of materials of greater strength, although the author is of opinion that for reliability the old charcoal iron has not yet been excelled by its modern competitors in the various qualities of steel. An iron wire rope reaches its limit of safety at 3000 feet, one made of steel wire at 4790 feet, and one of plough steel as 7185 feet. The difficulty of raising minerals from increasing depths has been overcome by making the ropes of a taper form, so that as the rope is paid out and the suspended weight increases, so also does the sectional area of that part of the rope supporting the weight go on increasing. As, owing to inertia, the working load increases considerably with augmenting speed, so that a velocity of 30 feet per second actually doubles the load, the ropes are severely tried just where they show over the drum from which they are suspended when the cage is at the bottom of the pit. To avoid the danger arising from this source 6 feet or 7 feet of the wire rope is cut off from the cage end every two or three months and newly fastened, so that the severe straining mentioned comes on different parts of the rope. By this means the life of a wire rope, with proper care in other respects, may be safely taken at two and a half years. Owing to internal corrosion, which it seems impossible to arrest by any known means, it is quite unsafe to work them longer for winding purposes, whatever their appearance may be after this period of use, or even of rest, if they have been exposed.

Winding Engine at the Wingate Grange Colliery.—Illustrations are given in *Engineering* * of a vertical winding-engine recently constructed at the Wingate Grange Colliery, Durham. The Lord pit is 110 fathoms deep, and two-deck cages carrying two tons are used. In full work the engine is capable of raising 1200 tons per day of eleven hours. The 18-foot winding drum is carried by girders immediately over the cylinder, which is 40 inches in diameter, and has a stroke of 6 feet. The distributing valves are of the Cornish hand-geared type.

* Vol. l. pp. 446–447, 451.

Electric Signalling for Mine Cages.—Drawings are published * of the Schulz arrangements of electric signalling as applied to shafts used for hoisting purposes. It was especially designed to meet a case where it was found impossible, owing to the shaft being out of the vertical, to communicate from the cage in the manner at first adopted. Other similar arrangements are also described.

Pump for Mining Purposes.—Mr. G. B. Walker † describes the Parker and Weston pump for colliery purposes. This pump is of the direct-acting class, and is made to work either simple or compound. It is fitted with a patent chest, which is driven either by steam or compressed air, no mechanical appliances such as tappets being used to actuate the valve. Long strokes in proportion to the diameter are employed, and any speed from one to two hundred strokes per minute can be used. After a description of the valves and method of working, the author states that he has had eighteen at work, the largest having a steam cylinder of 25 inches, and double-acting ram 8½ inches in diameter, the stroke being 3 feet. This pump raises water from a depth of 95 yards. Ordinary piston or ram pumps are used. Experience shows that these pumps give no trouble in working, are not liable to excessive wear, and will start themselves after accidental stoppage.

Compound Pumping Engine.—The *Engineer* ‡ gives a description, accompanied by a plate, of a large horizontal pumping engine built for the South Staffordshire Mines Drainage Commissioners. The engine has 52-inch and 90-inch cylinders by 10 feet stroke. It works two 27-inch plunger pumps each 10-foot stroke, forcing to a height of 500 feet. The engine is provided with a surface condenser, through which passes all the water which is pumped. The pistons are connected to the crosshead by three piston rods, one for the high pressure and two for the low pressure cylinders, and the pump rods are worked by two angle-bobs. The two rods balance one another, but provision is made for throwing one out of gear in case of disablement, and arrangements are made so that the single pump can still be driven.

Pumping at the Karwin Colliery.—J. Kohout § states that in sinking a narrow shaft at this Austrian colliery, a depth of over 30

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 133, with numerous illustrations.

† *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 11–15, one plate.

‡ Vol. lxxi. p. 74, with plate.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 581.

fathoms was sunk without any difficulty from the water, which was raised in a valve-tank or bucket; but at this depth a fissured sandstone was struck, which drowned out the miners, and the sinking had to be abandoned. An American duplex pump of the Knowles type was then ordered from New York, and was specially manufactured for use in the cramped space in which it had to be used. This pump is direct acting without any driving-wheel, and has two steam and two pumping cylinders. That employed had a capacity per minute of about 33 gallons of water raised 80 fathoms. It gave considerable satisfaction, and sinking again became possible.

Guttapercha for Colliery Pump Valves.—At the Maybach Colliery, Saarbrücken, the valve packing for the pumps consists of guttapercha, and this has now been in use for over five years without renewal. The pumps work at a pressure of 50 atmospheres, about 10 hours a day, and at a speed of from 60 to 72 double strokes per minute. The guttapercha should not be too hard, and should wear evenly.*

Hydraulic Pumping Arrangement.—Mr. R. T. Moore † describes J. Moore's hydraulic pumping arrangement, which enables two columns of water to be substituted for the ordinary pumping rods. These columns of water connect a pump at the surface and a motor cylinder underground, so that the piston in the latter travels correspondingly with that in the former. In case of leakage in one of the power pipes, there is a valve arrangement worked by a tappet on the piston-rod. This adjustment is automatic, and in practice is found to be very complete. The steam-engine can be placed at any point on the surface, and the pumps should preferably be placed so as to throw the water not more than 100 fathoms at a lift. Details are given of two plants in which this pumping arrangement is used. Of the work shown by the indicator diagrams of the steam-engine, 66·26 is obtained from the pump. Power lost in the friction of the engine gearing and surface is 10·24 per cent.; in the power pipes, 14·36 per cent.; and in the underground rams and pumps, 9·12. The power pipes can be led round bends, and the arrangements take but little room, so that the plant can easily be duplicated. Moreover, the pumps will work under water.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 518.

† *Transactions of the Mining Institute of Scotland*, vol. xii. pp. 168–174, two illustrations.

Petroleum Engines in Mines.—Mr. A. A. Atkinson * describes the 5 horse-power petroleum engine at the New Brancepeth Colliery. It is placed at a distance of 2400 yards from the shaft, and at a point 165 vertical feet to the dip. It is placed on a masonry pillar, which also carries the tank and other details. A heavy flywheel is used, and the explosion takes place at every second stroke. The cylinder is cooled by water supplied by a $\frac{3}{4}$-inch pipe. The ignition spark is supplied by a single bichromate cell. The engine runs at 140 to 160 revolutions, and works a pump at 20 to 23 strokes per minute. A 6-inch double-acting pump with a stroke of 18 inches is used, and forces the water for 1320 yards to a height of 72 feet above the suction end. Fifty gallons per minute are delivered when the engine runs at 170 revolutions. The exhaust from the engine is taken a distance of 33 yards from the engine, and issues at a temperature of 70° F. The most complete combustion takes place at higher speeds; when the speed is low the exhaust contains a large percentage of carbonic-oxide. This, however, is largely diluted by a good current of air which passes through the engine-house. The cost for 10 hours is 10s. 8d., whilst the cost of working the pump from the tail rope of the haulage system is calculated at £1, 14s. In this time 10 gallons of petroleum are used, or about $1\frac{3}{8}$ pint per horse-power per hour. Regulations are given for controlling the working of the engine and the carriage and storing of petroleum.

Mr. H. B. Budgett † also gives some notes on the working of two petroleum engines underground. One was situated near the bottom of the pit, where it had plenty of air, and gave satisfaction. The other was at the bottom of a long dip, where the air supply was imperfect and the water sometimes gained on the pump, so that it was working under considerable disadvantages. The exhaust from this latter had acted badly on the roof in the return air-ways. The first of these pumps deals with 100 gallons per minute for 10 hours per day, and delivers it to a height of 100 feet through 250 yards of piping. The second delivers 40 gallons per minute throughout the 24 hours to a height of 400 feet, through 1400 yards of piping. The author then goes into the question of the work done and the cost, and shows that the work for the cost is about the same in both instances.

Drainage of Water from Old Mines.—Mr. T. C. Hair ‡ describes

* *Journal of the British Society of Mining Students*, vol. xiii. pp. 76–85.

† *Ibid.*, pp. 85–92.

‡ *Proceedings of the South Wales Institute of Engineers*, vol. xvii. pp. 54–60, four plates.

two different plans which have been used for the drainage of water from old mines. At the Church Pit, Wallsend, four 21-inch lifting sets of pumps were let down an old 12-foot shaft. They were supported on large oak baulks at the top of the shaft, and were let down by large blocks fixed to the bottom end of the working parts of the pumps. The water was lowered to a depth of 110 yards from the surface, an average quantity of 2500 gallons per minute being raised. This method dispensed with the use of ground spears and blocks for supporting the pumps.

In the second plan adopted at the Shire Moor Colliery, a new pit had to be sunk to drain the water out of the old high main seam. The top of the pump was closed so as to retain the air in it while lowering in order to relieve the weight on the lowering tackle. A borehole was then put down to pierce the seam from the bottom of the shaft, precautions being taken to prevent the pressure of the water from blowing out the boring rods or injuring the men. This borehole was partly stopped by a plug as soon as water came through it, and a second set of pumps put in to reduce the water. After the water was got under, fresh boreholes were put down. The method of putting down these boreholes is described. A covering tube was fixed in the holes, and through this the boring rods worked. After the water was drained out, the sinking was recommenced. The pumps were supported partly by spear rods and partly by cross baulks in the shafts, and they were lowered by unscrewing the holding bolts sufficiently to allow the pumps to slip downwards to the desired extent. From 2000 to 3500 gallons were raised per minute.

Theory of Mine Ventilation.—In a paper read before the *Société de l'Industrie Minérale*,* M. Rateau endeavoured to prove that Murgue's theory of ventilation is only approximate, and that the formulæ connected with it should be employed with care. Even the hypotheses on which the theory is based are subject to discussion. For example, the supposition that the fluid moving along the roadway is displaced in sections is not realised in practice. The author is, however, of opinion that the theory he criticises should not be abandoned, for, until a better one is brought forward, it is capable of giving useful indications, quite approximate though it be. Moreover, in the majority of cases, an approximate result suffices.

As a result of the reading of this paper, it was decided to appoint a

* December 6, 1890.

committee to make a series of tests with the ventilating fans existing in the Loire coalfield.

Ventilation in Driving Levels.—G. Engeleke * describes the method of ventilating narrow workings at the Dudweiler Mine, Saarbrücken, by means of small fans driven by compressed air, and taking their supply from the main air-ways. Two forms of Ser fan are used, one of an early form, about 20 inches in diameter, and driven by a strap from the engine; the other is slightly larger, and its axis carries the crank of a driving engine with a 2-inch stroke, so that no intermediate gearing is used. Twenty-one of these latter fans are in use, and they cost about £29 each. Compressed air for driving these fans and for other underground work is supplied from three wet compressers with an aggregate of 150 horse-power. The air is compressed to four atmospheres and supplied by pipes, of which there are over 5 miles in the workings. The diameter of the pipe varies from 5·11 to 1·18 inches, and the pressure falls to two atmospheres in them at the extreme limits of the workings. The fans are kept locked in, and are under the charge of a special attendant.

Ventilation by this means is much better than when bratticing is used; the smoke from blasting is very quickly removed and the faces are cooled. The volume of air delivered by these fans varies from 180 to 724 cubic feet per minute, at distances from 150 to 293 yards from the inlet, when the fans are running from 189 to 435 revolutions per minute. There is a certain amount of loss at the joints and resistance at the bends, but two or three men can be supplied with sufficient air at 300 yards from the intake. The author then enters into the question of cost. Parallel drifts and stoppings for 200 metres (218 yards) cost £168; brick brattice, £41, 10s.; and fans and pipes, £44, 11s. In the cost given when brattice is used no account is taken of the extra work done at the main fan.

Fire-Damp.—E. Homann † draws attention to various researches relating to the occurrence of fire-damp in mines. Jicinský observes that while a rapid fall in the barometer would appear to exert some influence on the escape of fire-damp from coal, it certainly acts much more powerfully by causing the expansion of the gas stored up in old

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxviii. p. 286.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 72–77, 86–88, 98-100, 118-121, 129-132.

workings. A rapid and long-continued rise of temperature in the mine also leads to an increase in the escape of gas, caking coal giving more than non-caking coal, and a solid coal less than a softer or more broken variety. The causes of explosions in metalliferous mines is also discussed, the author considering the various views expressed by Daubrée, Castel, Brough,* and others.

Fan Experiments.—Mr. M. Deacon † gives the results of a Capell and a Schiele fan working on the same air-ways, shafts, and drift, and driven from the same engine at the Shirland Colliery. The following are the dimensions of the fans :—

Fan.	Diameter.		Width of Vanes.				Diameter of Inlets.			Chimneys.					
			At Inlet.		At Tips.					Area at Base.		Area at Top.		Height.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.		Ft.	In.	Ft.	In.	Ft.	In.
Schiele . .	5	0	1	3	0	10	2	10	Double	12	3	12	3	1	10
Capell . .	12	6	5	8	5	8	7	4	Single	55	3	126	6	10	0

The fans were both driven by a belt from an 18-inch diameter and 24-inch stroke high-pressure engine. The Schiele fan is geared 6·15 to 1, the Capell $2\frac{1}{2}$ to 1. Both fans worked off the same drift, the Schiele fan being nearest to the upcast shaft. For each test the drift just before the inlets to the fan was divided into sixteen squares, and the air in each measured for one minute by anemometers. The engines were indicated while the air was being measured. Experiments were tried when both fans were producing 1 inch water-gauge, and then when the fans were running with equal peripheral speeds. Fully tabulated results are given ; the following table shows part of the results :—

Fan.	Revolutions of Fan per Minute.	Periphery Speed in Feet per Second.	Area of Drift in Square Feet.	Mean Velocity of Air Feet per Minute.	Volume of Air in Cubic Feet per Minute.	Water-Gauge in Drift.	Water-Gauge in Pit.	Horse-Power in Air.	I. H. P. of Engine.	Useful Effect of Steam used per Cent.	Fuel per I. H. P. of Engine per Hour, Lbs.	Fuel per H. P. in Air per Hour, Lbs.
{ Capell	110	71·9	83·8	717	60,084	1·00	0·70	9·46	15·90	59·50	9·9	15·7
{ Schiele	427	111·7	76·8	569	43,699	1·00	0·45	6·91	25·61	26·98	9·9	36·8
{ Capell	195	127·6	83·8	1411	118,241	3·25	1·80	60·50	87·40	69·20	9·9	11·5
{ Schiele	488	127·6	76·8	670	51,456	1·45	0·55	11·75	39·86	29·48	9·9	33·7

* *Journal of the Iron and Steel Institute*, 1889, No. ii. p. 331.

† *Proceedings of the Federated Institution of Mining Engineers*, vol. i. pp. 280–297, with two plates.

The Capell Fan at Berge-Borbeck.—M. Kattwinkel * gives an account of some experiments made by Mr. Herbst on a Capell fan erected at the Prosper I. Colliery near Berge-Borbeck, Westphalia, to replace a 39-foot Guibal fan. The maximum capacity of this fan was about 76,000 cubic feet per minute and 3·2 inches of water-gauge. The Capell fan is 12·3 feet in diameter by 6·6 feet broad, and with an entry 6·9 feet in diameter on both sides. The engine cylinders are 20½ inches in diameter and 31½ inches stroke. Trials were made at 72 revolutions, and when the engine was worked with full steam admission. Owing to leaky brattices, nearly one-fourth of the air did not pass through the mine, but in spite of this the efficiency of the fan was 52·039 per cent., or 5 per cent. better than the best fan reported upon by the Prussian Firedamp Commission. In trials with full steam, the draught was so strong that the anemometers could not be observed. From the amount deduced from the water-gauge, however, the efficiency is 51 to 53 per cent. of the indicated horse-power.

The Waddle Fan.—Mr. M. W. Brown † describes the "Waddle Patent (1890) Fan" as being similar to the old fan in which the air was discharged into the atmosphere at a high velocity. With the new fan this velocity was considerably reduced by the addition of a divergent outlet extending beyond the external ends of the blades. The long blades between the boss and the edge of the inlet ring of the fan are almost radial, and between the inlet ring and the periphery are arcs placed at angles to the radius, and adapted to meet the requirements of the mine to which the fan is applied.

One of these fans was erected at the Craghead Collieries, and a series of experiments was made as to its efficiency. The fan in question was 35 feet diameter to the ends of the blades, and 36 feet 4 inches diameter to the periphery of the divergent outlets. It was driven direct by a high-pressure horizontal engine. The following results were obtained, reduced to a periphery speed of 6000 feet, or 54·54 revolutions per minute :—

Experiment.	Volume.	Water-Gauge.	
I.	136,200	2·205	Mine with two downcasts only, and under ordinary working conditions.
II.	163,700	2·234	Ordinary working conditions.
III.	211,300	2·228	Separation doors open.‡

* *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xxxviii. p. 347.

† *Paper read before the North of England Institute of Mining and Mechanical Engineers; The Colliery Guardian*, vol. lxi. p. 320.

‡ Air supplied from three downcast pits.

A short discussion followed on the various advantages of the improvements which had been described, and it was stated that a 35-foot fan so arranged would give results equivalent to the old 42-foot fan.

The Ser Fan.—A new form of fan, at present in use only in France, is that designed by the late Professor Ser of the Paris School of Mines. It has vanes curved in the direction of movement, and is driven at a high velocity. A fan of this type in operation at the Moulin Mine in the Anzin Coalfield is described by A. Zsigmondy.* It has a diameter of 6½ feet, and makes 240 revolutions per minute. At the present time six of these fans are in use in the Anzin mines, the diameters varying from 4½ to 6½ feet. The Ser fan is characterised by the high value of the ratio of the observed depression to the theoretical depression. This ratio can at most reach 93 per cent. In the Guibal fan it is 65 per cent., and in the Pelzer fan 41 per cent. In the Ser fan it amounts to 60 per cent.

Damping the Air in Collieries.—At the Planitz Colliery in Saxony the air used for ventilation is caused to turn a wooden lap-wheel working in water. The flaps or blades of the wheel are thus being continually moistened, and a portion of the moisture given up to the incoming air.†

Coal-Dust in Mines.—A minute has recently been issued by the Secretary of State dealing with the question of coal-dust in mines. Attention is called to the results deduced by Mr. Hall from his experiments, which show that dust may be the cause of explosions even if fire-damp be absent. The necessity of laying the dust is pointed out, but no further legislation can be attempted till the question is more fully investigated.‡

A commission composed of Mr. Chamberlain, Lord Raleigh, Sir William Lewis, Professor Dixon, Mr. E. Bainbridge, and Mr. Fenwick has been appointed to inquire into the matter.§

Effect of Coal-Dust in Colliery Explosions.—Mr. H. Hall‖ has reported on a large number of experiments made by himself to test to

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxix. p. 96, with plate.

† *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1890, p. 126.

‡ *Industries*, vol. x. p. 36.

§ *Ibid.*, vol. x. p. 159.

‖ *The Colliery Guardian*, vol. lx. pp. 875–876.

what extent colliery explosions may be caused by blasting with gunpowder in colliery workings which are dry and dusty, but which are entirely free from fire-damp. The experiments were performed by firing one or two cannons placed in a shaft into which coal-dust had been riddled so as to make the air dusty. Three series of experiments were made on different dates, and under different weather conditions, and particulars are given of the temperature in the shaft, the amount of dust used, and the weight of powder fired. As a rule there was an updraught in the shafts in which the powder was fired. In most instances the dust ignited. Sometimes the explosion was very violent, and flame was projected many feet above the pit mouth. In the second series of experiments, at the Southport pit, 18 feet in diameter, the shaft was very wet, and out of six trials no explosion occurred. Full details of all these experiments are given in the report, and the subject is again dealt with by Mr. Hall in a paper read before the North Staffordshire Institute.*

If it could be held that the air in these experiments was free from fire-damp, the distance, according to Mr. W. N. Atkinson,† to which coal-dust alone could transmit an explosion was increased up to 200 yards. He thought, however, that coal-dust alone was quite capable of causing an explosion. There need not be any fire-damp present; and cases were cited to show that explosions have taken place in intake airways where there could only be dust and no fire-damp when these airways were used as haulage roads. The return airways were not traversed by the explosions, and they contained no dust, or, at most, only a little stone dust. It was, however, better to discuss remedial measures rather than the question of dust *versus* gas. Defective lamps, shot firing, gob fires, all tend to give rise to explosions of coal-dust or fire-damp, but all these factors have been looked after during the past few years. With regard to rendering the dust innocuous very little had been done, and it was in this direction that advance was necessary. The accumulation of dust on the roof, sides, and timbers was the most dangerous and the most difficult to get at. The only effectual ways of applying water to long lines of roads appeared to be either by conveying moisture in the air-currents, or by applying water under pressure from pipes laid along the roads, either by means of a hose pipe, or, preferably, by being allowed to escape from stand-pipes in the form of fine spray.‡

* North Staffordshire Institute of Mining and Mechanical Engineers.

† *Ibid.*, through *The Colliery Guardian*, vol. lxi. p. 160.

‡ *Ibid.*, vol. lxi. p. 492.

Mr. H. R. Makepeace mentioned the use of salt, and described the various appliances that had been used, such as watering carts with jets or with revolving spreaders, fixed water mains, &c. The spray from these mains might be further broken up by the use of compressed air, which was supplied by a second set of pipes laid side by side with the water pipes. He did not find that watering affected the roof or floor as long as no water was allowed to accumulate.

Mr. J. A. Bakewell described some experiments he had made with steam turned into the downcast. Only a small quantity could be used or a mist was created. As far as he had gone the roof and sides had not been much damaged, but the dust for the first 230 yards had been damped both on the floor and sides so that it would not rise. At a distance of 400 yards no effect was produced. In one respect the experiment failed, as it did not prevent dust rising from the tubs. He hoped to perform the experiment of turning steam into the workings at a week's end, and to keep them filled with a heavy mist. He was afraid, however, that this would damage the roof, and altogether he was not very sanguine about the result.

According to Mr. E. B. Wain, it would almost appear that the only really effective way of dealing with the upper dust blown from the tubs in transit was to go to the root of the matter, and moisten the top of every load of coal before it left the working-face, or at least at some main point before bringing it on the main haulage road. Only a small quantity of water would be needed on the top of each load to keep down the dust, and the drippings from the tubs would be sufficient to keep down the floor dust. In extreme cases it might be necessary even to damp the face of the coal.

In the resumed discussion on the effect of coal-dust, Mr. H. R. Makepeace gave the results of some hygrometric observations on the air in roads where the water spray was used, either with or without compressed air. The pressure employed varied from 200 to 476 lbs. in six collieries, and he had found no difficulty from choking of the nozzles. The time for working the jets varies; it depends on the air-current and other circumstances.*

Mr. W. C. Blackett† has observed explosions of dust in dry, dusty roads which act as air intakes, and thinks that too heavily charged boreholes, as well as blown-out shots, may cause explosions in some cases. Mr. Hall's experiments have shown greater violence of explo-

* *The Colliery Guardian*, vol. lxi. p. 699.

† Paper read before the National Association of Colliery Managers, February 21, 1891; *Colliery Manager*, vol. vii. p. 51.

sion in the deeper shafts. This result may be explained in part by the compression and disturbance of the air in front of the explosion. The various arguments against explosion of dust are considered.

Prevention of Dust Explosions.—For the prevention of danger of dust explosions in collieries, Meissner* of Dudweiler, Germany, describes a device which has been introduced into several German collieries. Water under pressure is forced into holes bored into the coal to the depth of 3½ feet and spaced about 10 feet apart. In the Camphausen Colliery, a pressure of 8 to 10 atmospheres through two tubes in eight hours impregnated a block 20 by 3½ by 5 feet. In the Kreuzgräben Colliery, water under pressure of 20 atmospheres in sixteen hours impregnated the coal as far as 13 feet above the highest hole. For the successful application of this method the water supply and pressure should be large and the coal should be firm.

Spontaneous Combustion of Coal.—The question of the spontaneous combustion of coal is dealt with by Mr. W. M. Shore,† with special reference to the brown coals of New Zealand, which are exceedingly liable to it. Several occurrences of fires or incipient fires due to this cause are given. In the first case the author carefully observed the rise of temperature in an abandoned heading where some falls had taken place. In some instances, the fallen material heats and then cools down again, but this only happens when the material is in large blocks and well ventilated. When the material is small, the fire will not occur till it is heated throughout. The first indication of heating is usually a slight dampness, which increases till steam issues from the top of the heap. The fire, however, appears at the bottom first, and the heat appears to travel fastest in the direction of the air supply. Crushed pillars are exceedingly troublesome, especially if the floor has a tendency to heave. The pressure on the pillars generates heat, and air finds its way through the cracks. In case the steam and smoke hang about the roof, it is very difficult to localise the outbreak. Seams lying at high angles with a strong roof and yielding floor have a tendency to crack, and the fissures become filled with small coal, which, by the combined effect of friction and slow combustion, tends to ignite. The fissures can often be found by the lines of condensed

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen, im preussischen Staate*, vol. xxxviii., 1890, pp. 358–362.

† Paper read before the Mining Conference, Dunedin, New Zealand, through the *Colliery Guardian*, vol. lx. p. 710.

moisture. The only safe remedy is to cut into the pillar with great precaution and to remove the obnoxious material. In doing this, a borehole should be kept well ahead, and water under pressure discharged through it. A spray jet of water should also be kept conveniently for instant use. Even under careful supervision an unexpected natural cleavage face or "soft back" may give rise to a fire. Steam-pipes may also heat the coal and commence a fire.

The author is quite in favour of using water, especially as spray for quenching fire and for cooling heated material. By its use work can often be carried on till the section is closed off. In opening up a colliery in a district liable to spontaneous combustion, the workings should be laid off in sections which intercommunicate as little as possible, and which are independently ventilated. The roof should be kept up till the robbing of the section is fairly under way, and all small coal should be removed at once, or at least turned over frequently. A good water supply should be laid on, and ventilation should be on the ascensional system. Only in extreme cases should the air current be reduced. In closing a district, great care must be taken in selecting the position of the stoppings. Temporary ones may be put up at the air inlets, but it is preferable to make them of soft clay or earth, or, better still, of cold well-rammed ashes from the rubbish heap. The movement of the ground soon renders these stoppings air-tight.

According to Mr. R. R. Tatlock * the conditions which favour slow combustion are the presence of a carbonaceous body which will burn if heated to redness, the presence of air or oxygen and moisture, and last, at least a moderate temperature. After these, the mechanical condition of the body is of the greatest importance. In order to determine whether it is the sulphur, the compressed or occluded gases, or the non-gaseous compounds in coal that cause spontaneous combustion, the author exposed several finely-pulverised samples of coal to the air to allow the gases to escape, dried them at 212° F., and determined the sulphur present in each as sulphuric acid. A weighed portion, exposed at 350° F. for 1¼ hour, increased in weight by about 2 per cent., but the sulphates present had not materially increased. This increase in weight is due to the absorption of oxygen, and the experiments show that this absorption is independent of the sulphur or the gaseous elements. Though the analysis of coal gives no clue as to its liability to heating, yet some light might be thrown on the question with regard to any particular coal by experiments of the above nature.

* *The Journal of the Society of Chemical Industry*, vol. ix. pp. 1112-1114.

Electric Lighting of Collieries.—A plant has been laid down for lighting Goulborne Colliery (both above and underground), and it is also intended to light the Edge Green Colliery. A Mordey alternator of 2000 volts and 12·5 ampères is employed, belt-driven from a horizontal engine. For lighting the engine-rooms, shops, and screens, glow-lamps of 16, 32, and 50 candle-power are used, while in the yard and sidings there are four 200 candle-power and two 400 candle-power "Sunbeam" lamps. There will be a hundred 16 candle-power glow-lamps in the two pits.*

An installation of the electric light has recently been fitted up at the Stanley Colliery, near Crook. The machinery is fixed on the surface, and consists of a pair of Tangyes' high-speed vertical engines (coupled), driving a 6000 Watt dynamo. Close to the dynamo there is a switch-board, with main cut-outs, voltmeter, &c., and from this there are led away three main circuits. Of these, the first supplies current to the screens and travelling belts, the second lights the pit-heap and underground, and the third the offices and workshops. The screens and belts are lighted by pendant lamps of 16 candle-power. On the pit-heap and round the shaft in each of the two seams 50 candle-power lamps are used. In the yard in front of the workshops there is fixed a 200 candle-power lamp, and on the gangway two 100 candle-power lamps are fixed. The stables, joiners' shop, smiths' shop, &c., are all lighted by 16 candle-power or 25 candle-power lamps.†

Safety Lamps.—Mr. H. W. Hughes ‡ gives some notes on several different safety lamps which he has practically tested underground for over a year. The conditions under which a lamp is used underground are very different to tests made at the surface, where the lamp is clean and carefully handled. The author speaks most favourably of the Hepplewhite-Gray lamp in its latest form, which has several modifications on that tested by the Royal Commission on Mine Accidents. Three inlet tubes only are used, but one is broader than the others and acts as a reflector. A shield plate in the hood covers the inlet holes, and the outer cone just reaches the height of this shield so as to occupy a position intermediate between the two rings of outlet holes. The crown of the lamp also contains outlets covered by a crimped covering plate. The main improvements on the first form, however,

* *Industries*, vol. x. p. 164.

† *The Colliery Guardian*, vol. lxi. p. 377.

‡ *Proceedings of the Federated Institution of Mining Engineers*, vol. i. pp. 255-264, with two plates.

are the substitution of a gauze cylinder for the chimney, the introduction of the above-mentioned cone to control the size of outlet, and the substitution of a conical for a cylindrical glass. Under ordinary conditions this form gives more useful illumination than any other lamp, as the conical glass allows the shield to be sufficiently out of the way for light to be thrown upwardly without tilting the lamp. With regard to its power of detecting small quantities of gas this lamp is undoubtedly superior to others, both because it shows smaller quantities and because it can take air from directly under the roof by means of its inlet tubes. Numerous experiments show that the lamp is safe in currents of high velocity, and it should practically be free from explosions as the air is introduced under the flame, so that the gas in it will burn before the lamp becomes filled with explosive mixture.

The Mueseler lamp comes second as a gas-detector, but it does not answer well in "dampy" or slow currents. Owing to the chimney, the products of combustion, when the lamp is tilted, are likely to mix with the feed air, and so extinguish the flame. The Morgan lamp is complicated, and does not appear to be in general use. It detects gas well, burns well in a good current of air, but badly otherwise. The light gets defective after several hours' use. The peculiarity in the locking device is that a cylindrical lead plug, notched on one side, is slipped through a hole in a projection on the oil vessel into a covered hole in the upper part of the lamp, where it is retained by a spring. This arrangement appears to be an improvement on the ordinary lead rivet, as time is saved. The Marsaut lamp, slightly modified, and under different names, is still a serviceable lamp. The Deflector gives a very good light, especially as soon as it gets hot. In it the Marsaut type is generally followed, but the inlet air is guided by a brass cylinder and a flanged ring a little distance above and secured to the outer gauze cone. By these means the inlet air is thrown down to the flame, and a clear up passage is left for the spent air.

Two parts of vegetable to one of mineral oil is mostly used as an illuminant, except in the Hepplewhite-Gray lamp, where it is too sensitive. A recent improvement consists in corrugating the wick in the wick tube. Another point to which but little attention has been paid is the use of iron or brass for the oil reservoir. On the continent iron is mostly used, here only brass is employed. The former is, however, preferable, as it does not conduct the heat so readily, and the oil is thereby kept from getting gummy. To sum up, the author prefers the Hepplewhite-Gray, its only drawback still being its liability

to go out if carelessly handled. Next to this the Deflector is preferred, as it burns brightly in slow and impure currents, gives a good light for a long time, and stands much ill-usage.

New Safety Lamps.—It being intended to introduce into the State collieries of the Saarbrücken district new safety lamps supplied with internal lighting arrangements, experiments were made with the Wolf and Seippel benzene lamps, with inside percussion lighting attachments, and also with a new lamp designed by Feige, of Bochum, which has an inside match.* The Feige lamp was tried both with benzene and oil. The experiments proved that the safety is almost perfect when using the percussion lighter of the Wolf and Seippel lamps, but the latter lamp is too heavy, and the light is somewhat obscured by the arrangement of the lamp. The Feige lamp is arranged much in the same manner as the Wolf benzene-lamp, and the same magnetic lock is also employed. The main difference lies in the lighting arrangement, which consists in the main of a revolving drum carrying a number of peculiarly prepared matches. When the drum is turned a match is brought immediately over a push, by the use of which it may be forced up into the interior of the lamp, and there ignited. This is accompanied, however, by a certain amount of danger, owing to the flame at the moment of the ignition of the match being too strong. The Wolf lamp gave much the best results.

Lighting Locked Safety Lamps.—Mr. J. Taylor † describes a means devised by Mr. Elsom for lighting safety lamps while locked. One or more matches are carried by a rod which passes through the oil reservoir, so that it can be manipulated like the wick-trimmer from the outside. The rod can be turned and moved up and down, so as to rub the match against a roughened surface close to the wick. The lamp is tilted so that the flame from the match ignites the wick. In a discussion which ensued on the reading of this paper, it was questioned whether the use of these matches would not be dangerous in case the lamp were extinguished by gas.

Miners' Electric Lamp.—Mr. G. E. Smith ‡ describes a miner's electric lamp which is arranged as nearly as possible in the form of an

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 580.

† *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 35–37 and 61, one plate.

‡ *Ibid.*, vol. ii. pp. 38–40, illustration.

ordinary safety lamp. Cells of a secondary battery are contained in the upper casing, which is of metal, and the glow lamp is protected by a cylindrical glass shield. The cells can be tested and removed separately if necessary. The smaller lamp weighs $3\frac{3}{4}$ lbs., and is said to burn seven to eight hours. Recharging takes four to five hours. There is also an attachment at the side for carrying another lamp in case it is required to examine the roof.

Messrs. Gauzentes and Strong * describe a form of electric miners' lamp. The cell in this lamp serves two purposes; it forms the containing vessel, and acts as part of the element. The composition of the parts is not given. It is stated that its weight does not exceed 2 lbs. 12 oz.; it gives a regular and constant light for ten hours; the cost of maintenance for a week's work, calculated at seventy to eighty hours, does not exceed 5d., all charges included; the battery can be guaranteed to last for five years; the interior resistance does not undergo any alteration during that period; and its illuminating power is $\frac{3}{4}$-candle.

Accidents in Mines.—Mr. J. Tonge † shows that since the introduction of safety lamps the conditions of mining have altered so that no arguments can be drawn from the number of explosions. During the past forty-five years, however, accidents from all causes have decreased from 1 in 219 to 1 in 530 men employed, and deaths from falls of roof and sides during the same period from 1 in 661 to 1 in 1135.

Mr. H. Hall ‡ also gives statistics showing the number of persons employed, and the number of tons of mineral raised, for each death in the various districts during the nine years 1873 to 1881, and compares these numbers with those obtained from the next eight years, 1882 to 1889. For the whole kingdom the figures are for the first and second periods respectively, one death to 893 persons or 332,912 tons, and to 919 persons or 379,656 persons employed.

Electric-Mining Machinery.—Messrs. L. B. and C. W. Atkinson § discuss the application of electricity to mining. In their paper it is pointed out in what way the conditions of mining work differ from those existing in other industries, and how they have been dealt with. Some of the machinery now actually employed is described.

* Paper read before the Inventors' Institute, December 17, 1890; *Colliery Guardian*, vol. lxi. p. 18.

† *Transactions of the Manchester Geological Society*, vol. xxi., April 14, 1891.

‡ *Ibid.*

§ Paper read before the Institution of Civil Engineers, February 3, 1891.

The use of compressed air was then discussed, and the results of experiments were given, showing that the efficiency of this method of transmitting power was 45·8 per cent. for an air pressure of 19 lbs. per square inch, decreasing to 25·8 per cent. for an air pressure of 40 lbs. From more recent experiments by Professor Kennedy, it was found that in practice an efficiency of 31 per cent. might be realised, or 45 per cent. if the air was heated before being passed into the motor. In the case of the electrical transmission of energy, except when distributed into very small units, there was little difficulty in obtaining 50 per cent. of the power expended in the engine, and there were cases in which an efficiency of 75 per cent. had been realised.

One of the most important points with regard to the employment of electricity in coal mines was whether a motor would be likely to cause an explosion. It was necessary in the case of a machine which perhaps might have to work for several hours without attention to guard against the possible accumulation of an explosive atmosphere around the brushes. For this purpose the authors had enclosed either the whole armature or the commutator only in a practically air-tight casing, and the method had been successfully applied to a motor of 40 horse-power. The temperature had been kept down to 70° F. above that of the atmosphere by allowing a sufficiently large cooling surface, namely, 2·3 square inches per watt. To meet the objection that if the fire-damp should leak into these covers the resulting explosion might be as disastrous as if they did not exist, it was pointed out that whenever the proportion of marsh-gas to air exceeded 3 or 4 per cent., combustion would take place quietly, and the resulting carbonic anhydride would tend to prevent explosion in the case of farther leakage. Moreover, the authors proposed, in special cases, to introduce a constant supply of carbonic anhydride from a steel cylinder into the interior of the casing, thus preventing the ingress of an explosive mixture. Similar methods were adopted for enclosing the switches, and sparking was prevented by providing a resistance-coil of small self-induction, which was always connected to the ends of the magnetising-coil so as to form a path through which the current in the latter might continue even when the main circuit was broken. The switch itself also had a resistance-coil connected to the several points with which it made contact, so that by slowly opening the circuit sparking was practically done away with.

The application of electricity to pumping in mines was then described and illustrated. The use of belts for driving was not recommended

on account of the want of space and the difficulty of keeping them in good condition in dirty and wet situations.

The employment of electric power for actuating coal-cutting machinery was suggested in 1873 by Mr. Henry Wilde, and first practically applied by Mr. F. Mori, in 1887, whose machine was illustrated. It had a cutter of the bar type, revolving upon its axis, and was driven by a dynamo having a normal output of 10 horse-power, situated at a distance of about a mile. Their next machine was one in which the armature-shaft itself was made to carry the cutter-bar. Later developments of these electrical coal-cutters were given. The proper form and dimensions of the cutters were then discussed at some length, the authors preferring the bar type to that in which the tools were fixed into the periphery of a disc, not only as being less liable to be held fast by a fall of coal, but as cutting to a much greater depth. The cutter-bar ran at the rate of 500 revolutions per minute, and on an average, including stoppages, from 20 to 30 square yards per hour might be cut in fairly hard coal. At Lord St. Oswald's colliery at Nostell, 55 yards were bared to an average depth of 3 feet 8 inches in 75 minutes. The relative cost of cutting coal in this way and by hand showed a difference in favour of the machine of 1s. 6d. per ton.

An electric boring-machine was described, and also an arrangement for driving an Ingersoll percussive rock-drill by electricity, as well as a special form of dynamo adapted for use in transmitting power for electric mining-work, with a high voltage.

The authors arrived at the following conclusions:—

(*a.*) That electric power was destined to become an important factor in mining mechanics, on account of—1. The facility with which it could be used with machines which required to be moved from time to time. 2. The great economy in first cost and reduced cost of working owing to its efficiency being higher than that of compressed air, or any other medium of power transmission. 3. The smaller cost of maintaining the cables, as compared with piping, on shifting floors in roadways, &c.

(*b.*) That the methods described were sufficient to obviate all objections to the use of electric motors in coal-mining, whether by excluding inflammable gases or by constructions which would allow of their safe combustion.

(*c.*) That the experiments, trials, and practical work, extending over four years, showed that—1. Electrical pumps might be used with advantage and economy for mine-draining. 2. Electrical coal-cutters

could replace hand-labour, with saving in cost, and increased production of coal. 3. Electrical drilling-machines were available in place of machinery worked by hand or compressed air.

A large electric pumping, hauling, and lighting plant has recently been put down at the Hyde Lane pit of the Dukinfield Coal and Cannel Company. The power is conveyed a distance of 700 yards, and the main object for which the plant has been erected is to pump water out of the dip workings to the bottom of the shaft at the rate of 10,000 gallons per hour, and the vertical height to which the water is raised is 160 yards along an incline 400 yards long, dipping 1 in 2½. A pair of horizontal high-pressure steam-engines, 14¼-inch cylinders, 2-feet stroke, running 96 revolutions per minute, with 80 lbs. of steam pressure on the boilers, drive the dynamo, which is capable of giving an output of 220 volts and 200 ampères, or 60 horse-power, at its normal speed of 500 revolutions per minute. The motor, which is of the same type of machine as the generator, will give out 40 effective horse-power, running at 700 revolutions per minute. This machine drives direct on to the pulley or pump shaft by a 10-inch link belt; the pumps make 40 strokes per minute. The pumps are of the horizontal type, having four single-acting rams 8 inches in diameter, 8-inch stroke; two sets of pumps are mounted on each bed. The pump-house, which has been cut out of the solid rock, is brick arched, about 50 feet long by 15 feet by 10 feet high, and is lighted by four electric lamps of 16 candle-power each. The water is conveyed up to the shaft through 400 yards of 6-inch wrought-iron piping. The generating dynamo on the surface supplies the current also for the general lighting of the colliery, both on the surface and down the pit, by incandescent lamps, varying from 16 to 50 candle-power. This plant has been working very satisfactorily for about three months, but the hauling arrangements which form part of the scheme are not yet complete. These will consist of two similar motors of 20 horse-power each, fixed at the top of two main hauling roads, coupled through gearing to the hauling apparatus.*

In the report of the Chief Inspector of Mines of the State of Ohio is contained a description of applications of electricity to mining in that State. The first installation was made at the Whip-poor-will Colliery in Perry County. After some difficulty with the conductors and the locomotive, the plant was arranged to work successfully, and the Jeffrey coal-cutting plant was introduced shortly afterwards. Electric hauling and undercutting plant have also been installed in two other collieries.

* *The Colliery Guardian*, vol. lxi. p. 539.

An attempt is made to compare electrical haulage with steam haulage to determine their comparative efficiency, by using the approximate factors employed in railway practice for calculating the resistance of trains at various speeds on levels, gradients, and curves. The electric motors are reported to be drawing more than the loads calculated for ordinary steam locomotives of equal weight, but no great reliance can be placed on these results until more data are obtained.*

Rules Relating to the Use of Electricity.—In view of the gradually increasing utilisation of electricity as a source of power and for lighting purposes, both in mines and works, the accompanying rules relating to the precautions to be taken when using it become of importance. They were given by Mr. H. Morton † in a paper read before the National Electric Light Association:—

1. Do not touch or handle any electric wire or apparatus of any sort while standing on the ground, or while in contact with any ironwork, gas or water pipe, or stone or brickwork, unless your hands are covered with indiarubber gloves, and you are provided with such properly insulated tools as have been declared to be safe and in good order by the electrician or other competent officer of the company. If it is at any time necessary to stand on the ground, or on any surface not insulated from the ground, while handling electric wires and apparatus, indiarubber boots or an insulated stool should be used. In moving wires hanging on or lying over the electric light wires, lamps, or fixtures, use a dry hand line.

2. Never handle any electric wire or apparatus with both hands at once when this can be avoided, and, if it is necessary to do so, be sure that no current is present, or that one or both hands are protected by rubber gloves or other efficient insulation.

3. When handling line wires, treat each and every wire as if it carried a dangerous current, and under no circumstances allow yourself to make contact between two or more wires at the same time.

4. Never open a circuit which has been in use without giving notice to the superintendent, or whoever is in charge, of your intention to do so, and at the same time request that the same line be opened at the main station, and kept open until you have given notice that your work on that line is complete.

5. In the dynamo room never go near the belts or dynamos, nor

* *The Engineering and Mining Journal*, vol. l. pp. 456–457.

† *Iron Age*, vol. xlvi. p. 611.

touch any apparatus unless you are fully informed and instructed how to do so.

6. Tools used by linemen should be provided with insulating handles of hard rubber or other equally good insulator. It is the duty of each lineman to look after his own tools, and see that they are in good order, especially as to their insulation. In construction work a space of at least 20 inches must be left between the holes for pins on the cross arms, so that a lineman may get to the top of the pole and work without danger.

7. Lamp trimmers and others engaged in the care of lamps must see that the switch putting the lamp in circuit is turned off before they handle the lamp in any way.

VIII.—*COAL WASHING.*

Coal-Separating and Washing Plant.—Detailed illustrations are given in *Engineering** of a Lührig coal-separating and washing plant. The plant treats 1500 tons per day, the output of three pits, and consists of a dry separation or coal-washing plant proper, with means for dispensing with settling ponds by treating the water. Elevations, plans, and sections of the plant are given. It consists of (1) a screening plant; (2) the coal-washing plant proper; (3) plant for handling automatically the finest material contained in the water used for the washing, to obviate the necessity for settling ponds; and (4) the loading plant. The whole process is designed to avoid breakage by rough handling of the coal, and to make the action as nearly as possible automatic. The coal is brought in hutches by wire ropes, and is discharged by tumblers on to vibrating screens with 2-inch round holes. The lump coal passes on to the travelling belts, which are made of spaced round rods instead of plates. The dross from these picking belts and from the screens is taken by an elevator to the washery. The machinery in the dry separator house is driven by a separate engine, so that loading can go on continuously. The dross from the screens and belts is passed through revolving trommels, and all sizes above $\frac{5}{8}$ inch pass to the jigs. The intermediate quality from these jigs is crushed and re-treated. The fine coal, under $\frac{5}{16}$ inch in size, is treated in pyramidal separating boxes and felspar jigs. The dirty water

* Vol. i. p. 184, with plate.

is passed down along a trough against a slowly travelling creeper, which collects and removes the dirt as it settles.

A New Coal-Washing Plant.—At the Fohnsdorf Colliery, Styria, a new coal-washing plant has recently been completed. The coal is first separated by Briart separators into lumps, nuts, and smalls. The two former sizes have any shale present removed on Cornet belts. The small coal is then again treated in separators which divide it into sizes, and is then subjected to washing. The plant is lit by the aid of 200 glow-lamps and 5 arc lights. A hot-water engine of 40 horse-power is employed for traction purposes.*

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 565.

PRODUCTION OF PIG IRON.

CONTENTS.

I.—*BLAST FURNACE PRACTICE.*

The History of the Blast Furnace.—A. Ledebur * in publishing some drawings of ancient blast-furnace plant, glances historically at the inception and rise of the modern methods for the manufacture of pig iron. The drawings re-published by the author relate to the year 1716, but he observes that the furnaces probably differ but little in form from those of a century or two earlier.

The Ilsede Blast Furnaces.—This steelworks possesses three blast furnaces, of which two are always in blast. In 1890 the two in blast were No. 2, blown-in during September 1886, and No. 3, blown-in during October 1884. The blast was continuous, the average daily output for each furnace being 176·3 metric tons. During the autumn months the output reached 192 tons a day.†

The following table shows the working results of each furnace :—

	Furnace No. 2.	Furnace No. 3.
Capacity, cubic feet	451	308
Pig iron produced, metric tons	62,483	66,249
Ore used, metric tons	167,681	184,805
Coke used, metric tons	53,546	60,730
Yield of ore, per cent.	37·26	35·84
Charge per ton of iron :—		
Ore, tons	2·668	2·789
Coke, ton	0·857	0·917
Charcoal, ton	0·009	0·009

* *Stahl und Eisen*, vol. xi. pp. 219-224, three illustrations.
† *Ibid.*, vol. xi. p. 368.

The total charge was thus 3·132 tons and 3·084 tons for each ton of coke used. Basic Bessemer pig iron was the metal made.

The actual cost of the ton of pig iron was 33·44 shillings as compared with 26·68 shillings in 1889. The metal made in No. 2 furnace was a much brighter and more largely crystalline pig iron than that made in No. 3. furnace, and the temperature of the blast was from 70° to 80° C. higher. This will account for the less amount of coke used in No. 2 furnace as compared with the consumption in No. 3.

Ironworks of the Rhine Provinces.—Kraft * describes the principal ironworks in the Rhine Provinces, giving full details of the furnaces and descriptions of the products.

The Concordia Works at Engers smelt Nassau brown and red hæmatites with Westphalian coke in two old small blast furnaces and two new large ones. The new furnaces have four tuyeres. They are 52 feet in height, 6¼ feet in diameter at the top, and 11½ feet in diameter at the boshes. The blast is heated in three pipe stoves and in two Cowper stoves, the temperature being measured by Hobson's pyrometer. A portion of the slag is granulated and used as sand. The works employ 380 men, and produce 45,000 tons of pig iron.

The Sayner Works, belonging to F. Krupp, produce machine castings, pipes, &c. In 1886, from two cupolas and two reverberatory furnaces, 634·4 tons of castings were produced, 87 men being employed.

The Mühlhofen Works, also belonging to F. Krupp, in 1886 smelted 127,278 tons of iron ore, with 30,530 tons of limestone and 64,443 tons of coke, to 63,518·8 tons of pig iron, which was forwarded to Krupp's steelworks at Essen. There are three large blast furnaces with Gjers stoves, pneumatic hoists, two horizontal and two vertical blowing engines.

The Germania rolling mills at Neuwied produce chiefly sheet iron and tin-plates. The annual production is 24,000 tons.

The Hermanns Works at Neuwied, also belonging to F. Krupp, contain one old and three new blast furnaces; the latter being 60 feet in height, with four, five, and six tuyeres. Two of the furnaces run on Bessemer pig iron and one on forge pig iron. The blast is heated in three vertical Gjers stoves to 550° C. The blast furnaces produce 80 tons of pig iron daily, and 300 men are employed. The entire out-turn

* *Glaser's Annalen*, vol. xxviii., Nos. 316, 317, 320, 321.

is taken by Krupp's steelworks at Essen. All the ores smelted are from mines belonging to the firm; they consist mainly of red and brown hæmatites and spathic ores, of which the following are typical analyses :—

	I.	II.	III.	IV.	V.	VI.	VII.
Iron	55·41	53·05	49·30	50·40	47·25	56·88	56·58
Manganese	1·75	9·84	10·15	2·53	0·98	1·12	1·58
Copper	0·048	0·046	0·105	0·075	...	trace	...
Phosphorus	0·081	0·017	0·010	0·071	0·179	0·009	0 017
Lime	...	...	...	...	...	4·07	...
Residue	12·20	4·76	10·51	13·57	21·27	5·75	10·00
Water	...	1·63	10·48	0·10	1·73	...	...

I. Red hæmatite from the Bindweide Mine, Siegerland ; II. spathic iron ore from Bollenbach ; III. brown hæmatite from Hochhausen, Nassau ; IV. spathic iron ore from the same locality ; V. red hæmatite from the Friedrich Mine, Nassau ; VI. Spanish red hæmatite from Bilbao ; VII. brown hæmatite from the same locality.

The Rasselstein Works at Neuwied, which have been in the possession of the Remy family since 1784, were the first in Germany to produce rails. At the present time they produce tin-plates and Clapp-Griffith steel. For the treatment of grey and white Siegen pig iron, with 0·1 per cent. of phosphorus and 6 per cent. of manganese, there are two cupolas and two fixed converters. Some 600 workmen are employed.

The Heinrich Works at Au on the Sieg produce annually some 36,000 tons of spiegeleisen, with 6 to 30 per cent. of manganese, from mines belonging to the company. There are two blast furnaces and four Cowper stoves. At the works 120 men are employed, and 1100 in the mines.

The Wissen Works at Wissen on the Sieg were built in 1780, and produce spiegeleisen and forge pig iron in two 4-tuyere blast furnaces 60 feet in height and 15 feet in diameter at the boshes. The blast is heated to 450° to 500° C. in Gjers stoves, four to each furnace. The charge for Bessemer pig iron consists of 30 per cent. of spathic iron ore, 30 per cent. of brown hæmatite, 18 to 20 per cent. of specular iron ore, and 20 to 25 per cent. of burnt pyrites. For forge pig iron the charge consists of 40 per cent. of spathic iron ore, 20 per cent. of brown hæmatite and 20 per cent. of red hæmatite for good brands, and 20 per cent. of tap cinder for poorer brands. The consumption of fuel amounts to 0·9 to 1·2 ton of coke per ton of pig iron, and the daily production is 55 to 65 tons. The products have the following compositions :—

	I.	II.	III.	IV.	V.	VI.
Manganese	11·12	14·11	5·50	7·12	5·76	1·84
Phosphorus	0·06	0·08	0·09	0·10	0·32	0·45
Copper	0·25	0·17	0·29	0·23	0·18	0·08
Silicon	0·25	0·30	2·85	...	...	...
Sulphur	0·03	0·01	0·01	...	...	...
Carbon	4·10	4·40	4·00	...	...	...

I. Spiegeleisen with 10 to 12 per cent. of manganese; II. the same with 12 to 15 per cent.; III. Bessemer pig iron from German ores; IV., V., VI. forge pig iron of different qualities.

The Alfred Works at Wissen, belonging to the same company, produce 90 tons daily of spiegeleisen, with 20 per cent. of manganese. There is one 6-tuyere blast furnace 72 feet in height and 20 feet in diameter at the boshes, with three Cowper stoves for heating the blast to 900° or 1000° C.

The Friedrich Works at Herdorf produce principally spiegeleisen from raw and roasted spathic ore, and brown hæmatite from the Burbach and Daaden districts, and from manganese ores from the Lahn with 20 to 45 per cent. The roasted ore averages:—

Iron.	Manganese.	Copper.	Phosphorus.	Residue.
47 to 49	0 to 10	0·2	0·0	10 to 12

The coke from the Dortmund collieries contains 8 to 10 per cent. of ash. There are two blast furnaces, 52 feet and 69 feet in height respectively. For one furnace the blast is heated to 580° C. in three Gjers stoves, whilst for the other three Cowper stoves are employed. The consumption of fuel is 1·03 ton of coke per ton of spiegeleisen, the composition of the latter being as follows:—

Manganese.	Phosphorus.	Copper.
6 to 21	0·07 to 0·09	0·2 to 0·25

For forge pig iron the consumption is 0·89 ton of coke per ton of iron, the composition of this pig iron being:—

Manganese.	Phosphorus.	Copper.
3 to 4	0·2 to 0·3	0·2

At these works 93 workmen are employed.

The Seelenberger Works at Herdorf possess one blast furnace 54 feet in height, and produce spiegeleisen containing:—

Manganese.	Phosphorus.	Copper.
8 to 14	0·039	0·240

White and mottled pig iron of best quality is also produced; its composition being as follows:—

Manganese.	Phosphorus.	Copper.
4 to 5	0·15 to 0·25	0·25 to 0·3

The ores employed were spathic iron ore (I.), and brown hæmatite (II.), having the following compositions:—

	Iron.	Manganese.	Phosphorus	Copper
I.	47 to 48	10 to 11	0·0	0·05 to 0·10
II.	48 to 52	...	0·05 to 0·25	...

The coke contains 6 to 10 per cent. of ash. The blast is heated in two pipe-stoves. The daily production is 35 to 40 tons of spiegeleisen, or 40 to 45 tons of forge pig iron, 36 workmen being employed.

Krupp's Steelworks at Essen in 1826 afforded employment to 10 workmen. At the present time some 15,000 persons are employed. Crucible steel is made from weld iron and weld steel, produced in 54 puddling furnaces. There are 107 subterranean furnaces with coke firing, and 20 with regenerative firing. There is also 1 regenerative furnace above ground. There are 15 six-ton acid Bessemer converters, and 12 ten-ton open-hearth furnaces. The author gives a plan of these works, and describes in detail the various products. Altogether there are in these works, 3542 furnaces of various kinds, 439 steam boilers, 82 steam-hammers, 21 rolling-mills, 450 steam-engines, and 1622 machine tools.

A New Charcoal Blast Furnace.—A charcoal blast furnace has recently been erected at Jefferson, Texas. It is 60 feet high and 12 feet in diameter at the boshes. It has a closed top, two Durham iron stoves, and is expected to produce annually about 18,000 tons of pig iron suitable for wheels, local hæmatite and limonite being the ores used.*

The Use of Charcoal for Smelting Purposes.—Professor J. von Ehrenwerth † states that in Alpine districts about 7 tons of charcoal are used in the blast furnaces for every 10 tons of white pig iron produced. Assuming the waste charcoal resulting from the charcoal burning to be about 5 per cent. of the total quantity produced, it is evident that the annual loss due to this cause must be very large. The author discusses the methods of utilising this waste material, and considers that the best is in its conversion into gas, as is done at the

* *Iron Age*, vol. xlvii. p. 111.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 1.

Bångbro Steelworks, Sweden. The kind of producer used for this purpose is described. In principle it is a shaft-producer with a step grate.

Comparison of American and Cleveland Blast Furnace Practice.—Mr. W. Hawdon * gives some notes on American blast furnace practice and a comparison with the work done in the Cleveland district. The difference in the materials treated in the northern and the southern States is like that between those in Cleveland and on the west coast. In the southern States, as a rule, the plants are not so good or efficient as in the north. The chief aim of the American makers is to produce large outturns, whilst economy of fuel, which is cheaper than in England, is of secondary importance. They use blast at 9 to 10 lbs. pressure, and regulate it by the revolutions of the engine; whilst here the usual practice is to work all furnaces off the same air main, so that, properly speaking, there is no regulation of the blast as in America, where each furnace has its own main. They also use water cooling to a very large extent, not only at the boshes, but also around the well of the furnace, in a position that would be considered dangerous here. Their bronze tuyeres are also preferable. The stoves in the two countries are of similar construction. Owing to the severe winters the Americans keep a large stock of ore on hand, so that it can be mixed to produce a uniform quality. The coke, too, always comes from the same source, and renders the working uniform, though there is danger of stoppage of supply. Interchange of ideas, and the frequent rebuilding of the furnaces owing to the rapid driving, enables them to take advantage of all improvements. The circumstances which brought about the large makes and good practice in America are:—(1) Rich ores, apparently easily smelted, small in mechanical condition, and so easily acted upon by the gases and fuel, and being carefully mixed and selected, very uniform in quality; (2) good strong coke, also uniform in quality; (3) high pressure of blast, about 10 lbs. per square inch; (4) a temperature of blast similar to the British from regenerative stoves; (5) regular filling up of the charge in the furnace; and (6) a healthy rivalry, which is joined in by the workmen, to beat the record. The author had seen at the Edgar-Thomson furnaces three brooms, fixed on the top, one for the biggest day's make, one for the biggest week's make, and the third for the biggest year's make, indicating that it swept all before it.

* Paper read before the Cleveland Institution of Engineers; *The Colliery Guardian*, vol. lxi. pp. 362-363.

The best record of fuel consumed per ton of iron made in 1889 was in one of these furnaces, which had a capacity of 18,209 cubic feet, turning out 311 tons daily with the consumption of 1892 lbs. of fuel. More usual figures are an outturn of about 200 tons per day, with a fuel consumption of 2250 lbs. of coke per ton of iron. After referring to the short lives of the lining and bells, the author gives as his opinion that the Americans in driving had overlooked the saving to be effected in fuel economy, and the English in economising fuel had overlooked the economy that there was in greater makes, up to a certain point.

To equal American practice, the plant and practice must be the same. The extra cost in the case of two furnaces would be about £7500. With one furnace they had in six years' working the extra cost of two re-linings—£5000—and the loss of working for fourteen weeks, *i.e.*, seven weeks for each re-lining. The difference was thus £2500 added to the cost of a little extra labour in front of furnace. But there was to be taken off the saving in fuel and any profit made in the fourteen weeks the furnace was off for re-lining. The high pressure of blast put a greater strain on the machinery and furnace plant generally, and stronger and more costly engines were required, while the fuel consumption would be greater. The advantage appeared to the author to be on the side of English practice, though the Americans would not be persuaded that this was so. Adopting the figures of Mr. Gayley, manager of the Edgar-Thomson furnaces, the Americans consumed 21¼ cwts. of coke per ton of pig made. If they were smelting the 50 per cent. Rubio ore, instead of 63 per cent. American, they would consume 22¼ cwts., but in England this was done with 19 cwts., or 3¼ cwts. less. If an average over the last five years were taken, 19 cwts. was near the consumption of the northern States, and the difference of ore gave the English maker 1 cwt. of coke per ton; that at 7d. per cwt. would be £3033, 6s. 8d. per annum, or £15,165 to the good of the two British furnaces against the one American for five years. Thus he concluded that English practice was superior to that of America with all their hard-driving.

Mr. C. J. Bagley * compares Cleveland blast furnace practice with that in south of the United States. The furnaces are of about the same height and diameter, and work on ores containing 40 to 45 per cent. Since 1875 no new furnaces have been built in the Cleveland district, whilst the Americans have constantly been increasing their

* Paper read before the Cleveland Institution of Engineers; *The Colliery Guardian*, vol. lx. p. 873.

works and outturn, so that they now produce from 1000 up to 2000 tons per week from materials not much better than those in England.

Taking an ordinary Cleveland plant making 500 tons per furnace per week, if it were proposed to increase the production to 1000 per week they must double the number of boilers, engines, stoves, calcining kilns, and instead of one hoist to three furnaces they must have a separate hoist to each furnace. The well of the furnace would also be too small to hold the increased quantity of iron and slag brought down by the extra blast, and it would be necessary to relieve the furnace. Also a chimney to each furnace would be necessary instead of a chimney to three or more furnaces, as was frequently found; and the cold-blast main, hot-blast main, down-comers, steam pipes, and feed-water pipes would all be too small, so that larger mains and pipes would have to be put in. Finally, the chimney flues would be unable to deal with the immensely increased quantity of waste gases. The additional chimneys could be built, but he doubted whether the chimney flues could be enlarged throughout their length in any existing works in Cleveland, as they were generally underground and hemmed in on all sides by the foundations. The other difficulties might be got over, but this last difficulty was almost insurmountable. No doubt an installation on this scale might cost some £10,000 more per furnace, but the author estimates that the whole additional outlay could be recouped in twelve months. The calculation is made in this way—the coke used would be brought down from 23 cwts., the present average of Cleveland, to 19 cwts., or a saving of 4 cwts. per ton, which at current prices equals 4s., and a saving of at least 2s. per ton would be effected in wages, standing charges, interest on capital, &c., making altogether 6s. per ton, which on 50,000 tons a year was equal to £15,000 a year per furnace—an economy which, if taken at only £10,000 a year, would pay for itself in twelve months. If the engines were made condensing, no new boilers would be needed, as the same boilers would do nearly double the work; again, if the stoves were firebrick, they could be raised so as to give nearly double the heating surface, but where pipe stoves existed it would probably be necessary to demolish them altogether. The gases might be taken off by two down-comers instead of one, and if the works were cut in two, metaphorically speaking, the extra engines, chimneys, &c., being built at the other end, then the flues if blocked in the middle might be made to work to two chimneys. Chimneys also might be put to each stove, so as to relieve the pressure in the flues. It had been urged that there

was no profit in fast driving, that the expense of relining more frequently ran away with any advantage gained by driving; but that objection could not be raised in face of the foregoing facts, and if instead of taking five or six months for relining they did it in six weeks as in America, the objection disappeared altogether.

A Blast Furnace Record.—The Hattie-Ensley furnace at Sheffield, Alabama, is 17 by 75 feet, with three Whitwell stoves 18 by 55 feet, and two Dickson engines 4 by 7 feet. The following are analyses of the pig iron produced:—

	No. 1 Foundry.	Grey Forge.
Iron	92·790	94·268
Graphite	3·372	...
Combined carbon	0·240	...
Silicon	2·287	0·660
Sulphur	0·009	0·142
Phosphorus	0·583	0·550
Manganese	0·634	0·520
Undetermined	0·085	...

The best work of the furnace has been as follows:—

	Tons.
Week ending October 30, 1890	1139⅓
Best day (October 29)	185⅛
Average per day	162¾

Classification: 64 per cent. foundry, 36 per cent. forge.

The blast pressure averaged $5\frac{6}{10}$ lbs., the temperature 1151° F. The unused capacity of the engines was 26 per cent.

The following was the consumption of material in lbs. per ton of iron:—

Pocahontas coke	2319
Darlington limestone	1013
Ensley's Russelville ore	4258

The yield of the ore was 54 per cent.*

The Girard Blast Furnace, Ohio.—This furnace was put in blast on November 20, 1886, and during the four years ending November 20, 1890, made 215,000 tons of iron. The blast was continuous, except that the furnace was banked for eighty days through strikes. The daily output is now 170 tons.†

* *Iron Age*, vol. xlvii. p. 758. † *Ibid.*, vol. xlvi. p. 949.

Bell for Blast Furnaces.—A description is given in the *American Manufacturer* * of a new bell-drop for blast furnaces, which is to be used at Pueblo, Colorado. On either side of the hopper are cast iron standards which carry two cross I-beams sufficiently strong to take out the bell by means of block and tackle, and also to carry the operating lever. Four chains are attached to the bell and to the ends of four counterweighted levers supported on the cross beams. These levers carry four-fifths of the weight of the bell. The remainder of the weight and the weight of the stock is borne by the operating lever.

Slag-Waggons.—F. W. Lürmann † publishes drawings of a number of new slag-waggons, some variously arranged for tipping, and others provided with a tapping arrangement. They are of German construction.

Vertical Automatic Cut-off Blowing Engine.—Mr. J. P. Witherow ‡ of Philadelphia has designed a blowing engine of this kind which has the following dimensions:—

Steam cylinder, inches	42
Blowing cylinder, inches	84
Stroke, inches	60
Piston displacement per revolution, cubic feet	384
Usual working speed, revolutions per minute	30–40
Displacement at average working speed, cubic feet per minute	13,440
Pressure of air discharged, lbs.	5–15

The throttle valve is of the Web disc pattern. The piston-rod for both the steam and blast cylinders is one continuous piece of 5½ inches diameter. The engine is designed to run at a piston speed of 350 feet per minute.

New Form of Blower.—A new blower, of a form intermediate between a rotary blower and a blowing engine, is illustrated in the *American Manufacturer.*§ It is of the piston type, and consists of four rectangular chambers and pistons placed at right angles within a drum. The oppositely situated pistons are connected together, and each pair is connected by piston-rods to a stationary crank. The chambers are carried by a drum which rotates in an air-chamber, and by its rotation

* Vol. xlviii. No. 4, two illustrations.
† *Stahl und Eisen*, vol. xi. pp. 370–373, five illustrations.
‡ *Iron Age*, vol. xlvi. pp. 1078–1079, thirty-two illustrations.
§ Vol. xlviii. No. 8, p. 155.

round the fixed crank causes the chambers to work over the pistons. The machines are made to run from 4 to 80 cubic feet displacement per revolution, and can supply a uniform blast at 2 to 8 lbs. pressure.

Dessication of the Blast in the Manufacture of Pig Iron.—Mr. W. H. Fryer* shows that with air containing 0·8 per cent. of moisture there will be introduced about 89·6 lbs. of water into a blast furnace per ton of pig iron made with 22½ cwts. of coke. The effect of this moisture is to lower the temperature at the tuyeres so that more fuel and greater engine power have to be employed. The variations in the quantity of moisture cause constant variations in the working of the furnace, and in the nature of the iron produced. It also tends to make the iron red-short by the absorption of oxygen, and the hydrogen which is disengaged may be occluded by the metal, especially in the converter. It is, according to the author, quite practicable to dry the blast at a cost of 4½d. per ton of pig iron, without taking into account any saving or other advantage produced by it.

The author then takes the data given by Sir Lowthian Bell with regard to hot blast and the reactions in the furnace, and calculates calorimetrically the losses due to the moisture in the blast, and his results with blast at temperatures of 10° C. and 485° C. are as follows:—

Temperature of blast	10° C.	485° C.
Increase of make of pig iron, per cent.	31·42	15·07
Diminution of power required for blast, per cent.	67·50	15·71
Diminution of coke required in furnace, per cent.	21·51	12·01

Controlling Cowper Stoves.—C. Reinhardt † describes a gas suction and testing apparatus for use in controlling the working of hot blast stoves. The method adopted for such control is divided into three parts—(1) Aspiration of the gas from the stove; (2) conducting the sample into the testing apparatus; and (3) analysis of the gas. Drawings are given of the apparatus used for the aspiration of the gas, the main point being that the gas is not brought into contact with water, as this, as is well known, dissolves carbonic anhydride. To avoid this absorption it has been suggested to cover the water with a layer of petroleum, but the use of oil for this purpose renders manipulation difficult, and is not to be recommended.

For the purposes of analysis the author employs the well-known

* Paper read before the Cleveland Institution of Engineers, November 1890.

† *Stahl und Eisen*, vol. xi. pp. 46–48.

Bunte burette, with the Wolff modification of a thermometer fused into the burette. He describes by the aid of a sketch the apparatus he uses in order to convey the gas to this burette after its aspiration from the stove. The author then proceeds to discuss the method of analysis itself. He suggests various slight modifications, and observes that under certain conditions it may be advisable not to employ the Bunte burette at all, but to use in its place the Orsat-Fischer apparatus.

A Modified Whitwell Hot Blast Stove.—A modification of the Whitwell form of hot blast stove is illustrated in the *American Manufacturer.** The stoves are 20 feet in diameter by 60 feet high, and have four passes separated from each other by walls connected by the ordinary flues. Each division or pass has two gas inlets, one on either side of the stove. The gas inlet valves consist of an elbow on the rear of a plate, which is moved in or out over the openings in the gas flue. A temperature of 1200° to 1300° F. is maintained, and the loss is about 100° in an hour's blow.

II.—*CHEMICAL COMPOSITION.*

Analyses of French Pig Iron.—In an exhaustive report on the French mining and metallurgical industries, as presented at the Paris Exhibition of 1889, A. Gouvy † gives the following analyses of pig iron made by the Marnavel Company from local ores from Pont Varin-Wassy :—

	Foundry Pig Iron.	Grey Pig Iron.	White Pig Iron.	Mottled Pig Iron.
Carbon	4·00–4·50	3·50–4·00	3·00–3·50	3·20–3·70
Silicon	2·50–3·00	0·50–0·95	0·20–0·60	0·20–0·50
Sulphur. . . .	trace–0·05	0·03–0·07	0·04–0·08	trace–0·05
Phosphorus . . .	0·40–0·80	0·40–0·80	0·40–0·85	0·40–0·80
Manganese . . .	0·60–0·90	1·00–1·50	0·80–1·00	1·00–1·50

* Vol. xlviii. No. 1.

† *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxix. pp. 1–82.

The slag in each case contained :—

	Foundry Pig Iron.	Grey Pig Iron.	White Pig Iron.	Mottled Pig Iron.
Silica	31·50–32·00	29·50–30·00	29·50–30·00	28·00–28·50
Alumina . . .	23·50–24·00	21·50–22·00	22·50–23·00	22·00–22·50
Lime	43·50–44·00	47·50–48·00	46·50–47·00	49·50–50·00

The same works also produce manganiferous pig iron from local ores mixed with ores from Laurium in Greece, and from Romanèche in Saône-et-Loire. Analysis of this iron yielded :—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
3·50–4·00	0·10–0·35	trace–0·03	0·40–0·75	4·50–5·00

The corresponding slag contained :—

Silica.	Alumina.	Lime.
27·0–27·5	21·0–21·5	51·0–51·5

The high percentage of lime in this slag facilitates the production of bricks and of slag cement.

The ores employed gave on analysis the following results :—

	Ores from Pont-Varin.		Ores from St. Jean.	
	Raw.	Washed.	Calcareous.	Grey.
Loss on ignition	13·50	13·90	21·20	13·20
Silica	15·00	12·70	7·30	11·22
Alumina	12·10	7·17	7·35	10·35
Ferrous oxide	57·40	64·38	52·50	60·00
Manganous oxide	0·80	0·86	...	...
Lime	0·30	0·25	9·90	3·30
Phosphoric anhydride	0·62	0·55	1·45	1·50
Sulphuric anhydride	0·12	0·08	...	...
Metallic iron	40·18	45·05	36·75	42·00

At the Pompey Works, Meurthe-et-Moselle, the foundry pig iron had the following composition :—

Sulphur.	Silicon.	Phosphorus.	Carbon.
0·017	2·550	1·140	3·700

The pig iron from the works of Ferry Curicque at Micheville gave on analysis the following results :—

	Foundry Pig Iron.	White Pig Iron.
Silicon	2·40–2·75	0·30–0·60
Sulphur	0·02–0·05	0·25–0·50
Phosphorus	1·60–2·00	1·60–2·00
Carbon, combined	0·700	2·750
Graphite	2·500	2·750

The slag in the two cases contained:—

	Foundry Pig Iron.	White Pig Iron.
Silica	36·00	36·60
Alumina	16·70	17·85
Lime	42·40	38·44
Iron	1·38	2·60

With the exception of the last of the six blast furnaces built at Longwy, the Micheville blast furnaces are the largest in the east of France. Their dimensions are as follows:—

	Blast Furnace No. 1.	Blast Furnace No. 2.
	Ft. In.	Ft. In.
Height	65 7	65 7
Diameter of hearth	6 6	7 4
Diameter of boshes	21 3	22 1
Diameter of throat	17 2	18 0
Capacity	15,892 cubic feet	16,775 cubic feet
Out-turn in twenty-four hours	120 tons	130 tons

Analysis of manganese iron products from the St. Louis blast furnaces near Marseilles gave the following results:—

	Spiegeleisen.	Ferro-manganese.	Ferro-manganese.	Ferro-silicon.
Iron	65·80	47·14	6·23	82·60
Manganese	27·41	46·19	85·40	2·50
Silicon	0·23	0·14	0·46	12·60
Carbon, total	6·00	5·93	7·10	2·10
Graphite	0·28	0·14	0·56	2·10
Sulphur	0·009	0·005	trace	0·054
Phosphorus	0·062	0·095	0·168	0·088
Copper	0·019	0·024	0·060	trace

The Boucau blast furnaces produce interesting ferro-chromium alloys containing on an average 0·01 per cent. of sulphur and 0·06 per cent. of phosphorus. The following analyses show that in these products the percentage of carbon is in direct ratio to that of chromium :—

	Chromium.	Iron.	Carbon.	Silicon.	Manganese.
1	44·80	45·00	8·50	0·40	0·40
2	51·10	39·10	8·75	0·32	0·40
3	55·50	34·20	9·10	0·56	0·35
4	57·96	30·35	9·38	0·45	0·50
5	60·35	28·10	9·55	0·60	0·45
6	63·10	25·38	10·05	0·40	0·42
7	65·20	21·90	11·80	0·38	0·38

A specimen of ferro-chromium from the same works gave on analysis :—

Chromium.	Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
65·00	11·10	0·40	40·0	trace	0·06

Analyses of Pig Iron.—Dr. E. Prziwoznik * gives the following analyses of white pig iron :—

	a.	*b.*	*c.*
Carbon	4·291	4·090	...
Silicon	0·125	0·158	0·270
Phosphorus	0·050	0·083	...
Sulphur	0·015	0·023	0·039
Copper	trace	trace	0·035
Manganese	2·841	2·910	2·630
Cobalt and nickel	...	...	...
Arsenic and antimony	...	...	...
Iron	92·678	92·736	...
Totals	100·000	100·000	...

a. From Eisenerz, coarse grained ; *b.* fine grained ; *c.* from Alsó Sajó, in Hungary.

The Mode of Existence of Carbon in Iron.—A. Ledebur † again discusses this question. He refers to his previous articles,‡ in which

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxviii. pp. 406–407.

† *Stahl und Eisen*, vol. xi. pp. 294–299.

‡ *Journal of the Iron and Steel Institute*, 1889, No. I., p. 386.

he showed that carbon exists in iron in at least four forms—(1) graphite, (2) graphitic temper carbon, (3) hardening carbon, and (4) carbide carbon, the two first being generally classified as "graphite" and the latter as "combined" carbon. "Hardening" carbon, he adds, is evenly alloyed with the whole mass of the metal in which it exists, and it is to this form of carbon that the iron mainly owes its hardness, tenacity, and brittleness. "Carbide" carbon, on the other hand, forms a component of an iron carbon alloy, which is unevenly distributed through the mass of the cooled iron. As Abel has shown, this carbide contains about 7·2 per cent. of carbon.

The author has made a number of complete carbon analyses in steel, determining the total carbon by the copper-ammonium-chloride method; the carbide carbon by Müller's method,* using chromic acid and sulphuric acid as the oxidising agents; and the separation of the graphite without the carbide carbon by long-continued boiling of the iron with hydrochloric acid. From the difference in weight of the first and second of these the hardening carbon results, the difference between the second and third showing the percentage of carbide carbon. The following are the results:—

Cast Steel.

Sample A. was packed in sand and annealed for 35 hours. Sample B. was annealed direct in the furnace without covering.

Composition.	A.		B.	
	As Received.	Annealed.	As Received.	Annealed.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hardening carbon	0·14	0·08	0·36	0·16
Carbide carbon	0·44	0·52	0·62	0·92
Graphite and temper carbon .	0·00	0·01	0·00	0·01
Total carbon . .	0·58	0·61	0·98	1·09
Silicon	0·23	...	0·28	...
Manganese	0·18	...	0·20	...
Phosphorus	0·06	...	0·06	...
Sulphur	0·04	...	0·03	...

* *Journal of the Iron and Steel Institute*, 1888, No. I. p. 374.

Tool Steel.

This was examined in its hardened state and after tempering to a blue colour.

Composition.	As Received.	Hardened.	Hardened and Tempered Blue.
	Per Cent.	Per Cent.	Per Cent.
Hardening carbon	0·22	0·65	0·36
Carbide carbon	0·71	0·38	0·67
Graphite and temper carbon	0·00	0·00	0·00
Total carbon	0·93	1·03	1·03
Silicon	0·11	Not determined	Not determined
Manganese	0·11		
Phosphorus	0·03		
Sulphur	Not determined		

Soft Basic Bessemer Metal.

Composition.	Hardened from a Cherry Red Heat.	Hardened from Bright Redness.
	Per Cent.	Per Cent.
Hardening carbon	0·05	0·04
Carbide carbon	0·17	0·17
Graphite and temper carbon	0·00	0·00
Total carbon	0·22	0·21
Silicon	0·00	0·00
Manganese	0·58	0·58
Sulphur	0·04	0·04
Phosphorus	Not determined	Not determined

The second of these, that hardened from a bright red heat, was much harder and more brittle than the other, and the author at first attributed this to a change in state of the carbon, until analysis showed that no such change had taken place. He now attributes it to strains produced in the metal by the act of hardening. The colorimetric test showed in both instances only 0·17 per cent., a proof that in both cases the hardening carbon escaped determination.

White Pig Iron and Ferro-manganese.

The following analyses show that with an increase in the percentage of manganese in iron, the percentage of hardening carbon in the mass of the metal also increases :—

Composition.	White Pig Iron.	Spiegeleisen.	Ferro-manganese.
	Per Cent.	Per Cent.	Per Cent.
Hardening carbon	0·54	1·41	1·64
Carbide carbon	1·88	3·09	3·06
Graphite and temper carbon	0·16	0·00	0·00
Total carbon	2·58	4·50	4·70
Silicon	0·72	0·30	2·07
Manganese	0·10	11·11	46·54
Phosphorus	Not determined	0·16	Not determined

The carbide separated from the spiegeleisen was tested for manganese, and it was found that the iron and manganese in the carbide were present in the proportion of 32·54 to 5·45, slightly less manganese, that is, than exists in the main body of the metal.

Grey and Mottled Pig Iron.

Various samples of grey and mottled pig iron showed:—

Composition.	Deep Grey.	Grey.	Mottled.	Nearly White.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hardening carbon	0·00	0·19	0·17	0·72
Carbide carbon	0·44	0·34	0·73	0·92
Graphite and temper carbon	3·33	2·97	2·40	1·63
Total carbon	3·77	3·50	3·30	3·27
Silicon	2·77	2·20	1·02	0·70
Manganese	1·30	0·41	0·28	0·14
Phosphorus	0·80	0·51	0·59	0·56

Chilled Castings.

The hardened faces and softer backings of two chilled rolls were also examined. One of these rolls had stood well when in work, but the other had not:—

Composition.	Good Roll.		Bad Roll.	
	Face.	Backing.	Face.	Backing.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hardening carbon	0·58	0·45	0·55	0·46
Carbide carbon	2·43	0·46	2·35	0·70
Graphite and temper carbon	0·19	1·93	0·18	1·24
Total carbon	3·20	2·84	3·08	2·40
Silicon	0·83	0·80	0·88	0·86
Manganese	0·15	0·16	0·21	0·24
Phosphorus	0·88	0·88	0·83	0·87
Sulphur	0·10	0·10	0·12	0·14

Although these analyses do not afford an explanation for the difference experienced with the two rolls in practical work, yet they throw great light on the act of chilling itself. It will be observed from the above analyses that the carbon does not exist in the hard face, as had been previously assumed, in the form of "hardening" carbon, but that it exists for by far the greater part in the state of "carbide" carbon, and calculating from this the percentage of the carbide itself, which must have been present, it will be found that it formed about one-third of the total metal of the hardened face, and this calculation is supported by the evidence afforded by microscopic examination. The relation of the various forms of carbon to one another in chilled castings is, it will be seen, much the same as in the case of white iron.

Occurrence of Metallic Bismuth in a Blast Furnace.—According to C. H. Lündström * metallic bismuth is occasionally obtained in small quantities on tapping the pig iron from a blast furnace at Finshytte. It also occurs in larger quantities—sometimes up to 14 per cent.—in the zinc bears which form near the throat of the furnace. On blowing out the furnace, metallic bismuth and basic silicates of bismuth were found in some quantity near the furnace hearth.

III.—*BLAST FURNACE SLAGS.*

Composition of Slags.—Professor J. H. L. Vogt † endeavours to determine the state of combination in which alumina is present in slags. He makes use of the following analyses:—

	SiO_2.	Al_2O_3.	CaO.	MgO.	MnO.	FeO.	K_2O.	Na_2O.	Total.
I.	55·60	5·86	24·90	11·07	1·09	1·30	...	...	99·82
II.	56·73	7·04	18·80	16·43	0·10	0·48	...	...	99·58
III.	54·00	5·37	27·75	8·67	0·91	2·06	0·51	0·53	99·80
IV.	54·68	4·79	23·70	13·87	0·97	1·85	...	...	99·86
V.	50·64	2·52	16·79	7·27	20·11	2·38	...	...	99·71

I. Coarsely crystalline blast furnace slag from Sunnemo containing augite crystals; II. the same from Cartsdal; III. from Lofsjoen; IV. from Sunnemo; V. blast furnace slag with augite and rhodonite from Hofors.

* *Jernkontorets Annaler*, vol. xlv. pp. 312-313.

† *Zeitschrift für Krystallographie und Mineralogie*, vol. xviii. pp. 669-670.

On calculating these analyses, it is seen that aluminium is not, as in many natural augites, present as basic silicate, but as a so-called bi-silicate. Analysis I., for example, gives the formula :—

$$R_{11}SiO_3 + \tfrac{1}{11}\, Al_2Si_3O_9$$

or expressed in detail :—

$$CaMgSi_2O_6 + \tfrac{1}{20}\, CaMnSi_2O_6 + \tfrac{2}{10}\, Al_2Si_3O_9 + \tfrac{1}{4} - \tfrac{3}{10}\, Ca_2Si_2O_6$$

In each case the ratio Si : (R_{11} + $\tfrac{1}{3}$ Al_2) is so nearly equal to 1 : 1 that the entire mass could solidify as augite. In slags containing less silica, examined by the author, augite does not separate out, but olivine, or a silicate resembling melilite. In this way the proportion of silica in the residue is increased, so that it becomes possible for augite to separate out, provided that the mass does not rapidly solidify in the form of a glass.

The Calculation of Blast Furnace Charges.—Mr. F. F. Amsden * describes the calculations connected with a blast furnace charge, especially as regards the composition of the slag to be produced.

Taking the ratio of SiO_2 to bases as 0·85 the author calculates as follows :—

Limestone (100 *lbs.*).

		Per Cent.		Molecular Weight.		Equivalent.		Bases.	Acid.
SiO_2	=	3·85	÷	60	×	4	=	...	0·257
Al_2O_3 Fe_2O_3	=	2·15	÷	102	×	6	=	0·126	...
CaO	=	28·95	÷	56	×	2	=	1·034	...
MgO	=	20·02	÷	40	×	2	=	1·001	...

The bases added together equalling 2·161, and the acid being 0·257, there is an excess of base of 1·904 to be fluxed away.

By similarly treating the ash of the fuel, the following table is obtained :—

Fuel Ash (100 *lbs.*).

		Per Cent.		Molecular Weight.		Equivalent.		Bases.	Acid.
SiO_2	=	50·00	÷	60	×	4	=	...	3·3333
Al_2O_3 Fe_2O_3	=	45·00	÷	102	×	6	=	2·6470	...
CaO	=	1·50	÷	56	×	2	=	0·0536	...
MgO	=	2·25	÷	40	×	2	=	0·1125	...

* *Iron Age*, vol. xlvii. pp. 9–10.

Let Z = lbs. of limestone to be added to 100 lbs. of ash to form a slag in which $SiO_2 = 0{\cdot}85$: then

$$\frac{3{\cdot}3333 + 0{\cdot}00257\,Z}{2{\cdot}8131 + 0{\cdot}02161\,Z} = 0{\cdot}85$$

$Z = 59{\cdot}6$ lbs. of limestone per 100 lbs. ash, hence 100 lbs. of fuel (containing 8·5 lbs. of ash) will require 5·0 lbs. of limestone.

If $\frac{SiO_2}{\text{Bases}} = 1{\cdot}00$, then 100 lbs. of fuel will require 2·3 lbs. of limestone.

The following is the method of computing the quantity of limestone for each ore, "A" being given as an example. The analysis of the other ores can be gathered from the table below. When dealing with the slag composition only one-half of the manganese is computed, under the assumption that the other half enters the iron :—

"A" ore (100 lbs. Fe. = 48·5 per cent. and P. = 0·030 per cent.
1·96 ton ore per ton of pig iron (95 per cent. Fe.).
P = 0·059 per cent. in pig iron.

		Per Cent.		Molecular Weight.		Equivalent.		Bases.	Acid.
SiO_2	=	20·68	÷	60	×	4	=	...	1·3787
Al_2O_3	=	4·80	÷	102	×	6	=	0·2824	...
$\frac{1}{2}MnO$	=	0·29	÷	70	×	2	=	0·0083	...
CaO	=	5·38	÷	56	×	2	=	0·1921	...
MgO	=	2·35	÷	40	×	2	=	0·1175	...

$$\frac{1{\cdot}3787 + 0{\cdot}00257\,Z}{0{\cdot}6003 + 0{\cdot}02161\,Z} = 0{\cdot}85$$

$Z = 54{\cdot}9$ lbs. of limestone per 100 lbs. of ore.

If $\frac{SiO_2}{\text{Base}} = 1{\cdot}00$, then 100 lbs. of ore will require 40·9 lbs. of limestone.

Let it be supposed that the charge be composed of 12 barrows of fuel, 12 barrows of ore, and 6 barrows of limestone, and say that the fuel (6000 lbs.) will carry 9100 lbs. of ore, to be divided as follows :—

Ore.	Lbs.
2–12 "A"	1500
2–12 "B"	1500
2–12 "C"	1500
2–12 "D"	1500
4–12 "E"	3000

How many lbs. of limestone should be added to this ore mixture and fuel to produce a slag in which $\frac{SiO_2}{\text{Bases}} = 0{\cdot}85$?

It will be seen that :—

1500 lbs.	"A"	ore will require	15 × 55·0	=	825·0
1500 „	"B"	„ „ „	15 × 2·5	=	37·5
1500 „	"C"	„ „ „	15 × 90·8	=	1362·0
1500 „	"D"	„ „ „	15 × 13·7	=	205·5
3000 „	"E"	„ „ „	30 × 3·8	=	114·0
6000 „	fuel	„ „	60 × 5·0	=	300·0
Hence limestone to be added				=	2844·0

or 474 lbs. per barrow.

The composition of the slag may now be calculated by averaging the analyses of the ores, and adding the slag-forming ingredients in the fuel and limestone used per 100 lbs. of ore :—

Kinds of Ore.	SiO_2.	Al_2O_3.	(½)MnO.	CaO.	MgO.	Fe.	P.
Two barrows, A .	41·36	9·60	0·58	10·76	4·70	97·0	0·060
Two barrows, B .	19·68	4·86	3·00	9·76	14·60	98·6	0·054
Two barrows, C .	50·68	6·54	0·46	2·30	1·80	98·8	0·064
Two barrows, D .	11·00	1·22	0·16	4·80	2·16	131·0	0·024
Four barrows, E .	19·00	8·00	1·00	4·60	10·80	248·0	0·280
Totals . .	141·72	30·22	5·20	32·22	34·06	673·4	0·482
Average . .	11·81	2·52	0·43	2·68	2·84	56·2	0·040

66·7 lbs. of fuel per 100 lbs. of ore ; 31·6 lbs. of limestone per 100 lbs. of ore.

The slag is made up as follows :—

	Ore.	Fuel.	Limestone.	Total.	Percentage.
	Lbs.	Lbs.	Lbs.	Lbs.	
SiO_2	11·81	2·83	1·22	15·86	36·7
Al_2O_3	2·52	2·55	0·67	5·74	13·3
MnO	0·43	...	...	0·43	1·0
CaO	2·68	0·08	9·15	11·91	27·5
MgO	2·84	0·13	6·32	9·29	21·5
Totals . .	20·28	5·59	17·36	43·23	100·0

Mr. H. R. Hall * draws attention to some inaccuracies in the above calculation.

* *Iron Age*, vol. xlvii. p. 109.

IV.—*FOUNDRY PRACTICE.*

Melting Iron.—Mr. C. Smith * gives his experience in melting iron in foundries, especially in the use of Ohio softeners mixed with boiler and other steel scrap. The best results are obtained with a mixture of two sorts, preferably boiler iron and cast iron. Scrap boiler steel up to 50 per cent. has been used with Ohio Scotch, No. 2, with the production of good castings which were not too hard. The strongest test bar was cast from a mixture of three parts of boiler scrap to seven of the above-named pig iron. This metal was heated and reduced under a steam-hammer. When it broke it showed a stringy fracture. Other steels than boiler steel tend to harden the castings and to leave blow-holes. Old rails mix well with cast iron, but usually there are no appliances for cutting them up. Old files should be used but sparingly, as they tend to make the castings very hard. They are best used by placing them in the ladle before the metal is tapped into it. The boiler scrap should be charged into the cupola on the top of the bed of fuel, then the pig iron is put in and after that the coke. Each successive charge should consist of the same amounts of metal.

Feeding Borings into Cupolas.—The apparatus of Mr. J. Hansen for feeding borings into cupolas is illustrated in *Engineering*.† It is attached to the cupola opposite the melting space, and it consists of a hopper and casing all in one piece, in which is a worm worked by gearing and a hand crank. The worm feeds the borings from the hopper into the cupola. The tube through which the borings are fed is surrounded by an air-box, and another air supply tube is connected to the back of the worm casing. By these means the apparatus is kept cool and the borings are carried forward by the blast.

Aluminium in Iron.—Mr. D. Spence ‡ finds that 10 lbs. of ferro-aluminium to 2000 lbs. of pig iron removes all the blow-holes and makes good sound castings. It produces equally good results in cast steel. It takes away the tendency to chill in cast iron, and it reduces the shrinkage and increases the welding powers in both wrought iron and steel.

* *American Manufacturer*, vol. xlviii. p. 95.
† Vol. li. p. 257.
‡ *American Manufacturer*, vol. xlviii. p. 235.

Improved Moulding Machine.—An illustration is given in *Industries* * of an improved form of sand-moulding machine. It consists essentially of two vertical columns resting on a bed-plate, the distance between which is capable of adjustment according to the size of the pattern plate. In the columns are two spindles which carry the pattern plate in bearings, and are raised and lowered in the columns by means of a hand lever. The pattern plate can be turned completely round in its bearings, and the moulding boxes can be firmly attached to it by means of split keys or screws. The bottom box is first fixed to the plate and the sand rammed up; the whole is then turned completely over and the box lowered until it rests upon the table. The plate is then unfastened from the box and fixed in its bearings by the set screws, and, by means of the hand lever, is raised from the mould. This operation leaves the bottom box ready for use. The process of moulding the top box is exactly the same as for the bottom, taking, of course, the impression from the other side of the plate.

Mechanical Treatment of Moulding Sand.—Mr. W. Bagshaw † describes the mechanical treatment of moulding sand. Magnified views of the sand, both green and burnt, and of graphite and other materials used, are given. Generally speaking, good sand contains silica, 94 per cent.; alumina, 5 per cent.; and traces of magnesia and iron. Much lime should be avoided. A common mixture of facing sand consists of six parts by weight of old sand, four of new sand, and one of coal-dust. Floor sand requires only half the above proportions of new sand and coal-dust to renew it. German founders adopt one part by measure of new sand to two of old sand; to which is added coal-dust in the proportion of one-tenth of the bulk for large castings, and one-twentieth for small castings. A few founders mix street sweepings with the coal, in order to get porosity when the metal in the mould is likely to be a long time before setting. Graphite is effective in preventing destruction of the sand; but owing to its refractory nature it must not be dusted on in such quantities as to close the pores and prevent free exit of the gases. Powdered French chalk, soapstone, and other substances, are sometimes used for facing the mould; but next to plumbago, oak charcoal takes the best place, notwithstanding its liability to float occasionally and give a rough casting.

* Vol. x. p. 40, one illustration.

† *Proceedings of the Institution of Mechanical Engineers*, 1891, pp. 94–107, five plates.

The most primitive method of preparation is hand-riddling and stamping. Tough sand is undoubtedly obtained by these means, but the process is expensive on a large scale.

Other things being equal, the chief characteristics of a good moulding sand are toughness and porosity, qualities that depend on the manner of mixing as well as on uniform ramming. Indeed the same result would follow from want of attention to the one as to the other. Power riddling is the next advance, and this has been made to approach as nearly as possible to the former method by a succession of impulsive movements for opening out the sand. Roller mills answer well for hard sand containing stone, but when used with soft sand the castings have a tendency to scab occasionally.

Under the microscope the effect of pressure is seen to split up the grains into small angular fragments. It thus tends to make the sand lie too close. Schütze's centrifugal mixer combines the advantages of all the other plans. The sand is thoroughly mixed, so that gas readily escapes. Agglomerated sand comes out of the mixer as a powder, so that no previous sifting is required. In ordinary work the materials are placed in layers on the floor and shovelled into the machine by two men. Twelve tons an hour can be treated. In the machine a revolving table is mounted on the top of a vertical-spindle, and carries on its upper face a number of vertical pins or beaters, fixed alternately in a series of concentric circles. The table is driven by a 3-inch belt at the rate of 1200 revolutions per minute. The cover of the table has a hinge for turning it up in order to allow pieces of metal or other foreign substances to be readily taken out, which can be done at any time in only a few minutes. Falling upon the centre of the table from the hopper above, the sand is projected at a great speed from one row of pins to the next, until every part has been combed out. Round the outside of the table an india-rubber shield guides the sand into a circular heap after it has been whirled from the table.

Longer life of the sand is ensured by the complete intermixing of the materials. The reason for this may be seen in the protecting coat or shell. Moreover, a more even surface must result from the fact that, while the clay in the sand contracts under heat, the coal expands.

In order to test the relative toughness, sand mixed in various ways was pressed under a uniform load into bars 1 inch square and about 12 inches long, and each bar was made to project further and further over the edge of a table until its end broke off by its own weight. Old sand

from the shop floor had very irregular cohesion, breaking at all lengths of projection from ½ inch to 1½ inch. New sand in its natural state held together until an overhang of 2¾ inches was reached. A mixture of old sand, new sand, and coal-dust mixed under rollers broke at 2 to 2¼ inches of overhang; mixed in the centrifugal machine broke at 2 to 2¼ inches of overhang; mixed through a riddle broke at 1¾ to 2⅛ inches of overhang; showing as a mean of the tests only slight differences between the last three methods, but in favour of machine work. In many instances the fractures were most uneven, so that minute measurements were not taken.

Tests for porosity were also made by putting the various sands into a tube, and forcing air through. These, however, have no practical value, because the conditions when in contact with molten metal are quite different.

The power required, as shown by one machine, is 1 horse-power for 2 tons per hour. The cost is reckoned at 2d. per ton, whilst, with hand riddling, the cost is 2s. 1d. per ton. In the discussion it was stated that the pins wore out very rapidly in some cases, but in others this drawback had not occurred.

PRODUCTION OF MALLEABLE IRON.

Direct Manufacture of Malleable Iron.—Professor J. G. von Ehrenwerth * has published a pamphlet advocating the direct manufacture of malleable iron by a new method. Taking into consideration the fact that iron low in carbon in the fluid state readily takes up carbon until a maximum of 5 per cent. is attained, he proposes a direct process with gas-firing. High carbon iron is melted at a high temperature in an open-hearth furnace; ore is added, the iron in which is reduced by the carbon of the charge and taken up by the bath; and this is recarburised with solid carbon in the furnace itself, or in a pan, or in a small blast furnace. Ore is again allowed to act on the carburised material, and the process is repeated until the requisite amount of iron is produced. The slag, which is poor in iron, is removed from time to time. The higher the temperature, the more satisfactory is the run of the process.

The cost of production for 220 lbs. of ingot metal in Leoben is estimated at 4s. 10d. (or £2, 9s. 6d. per ton).

Fining of Iron.—According to Ranström,† the addition of lime during the fining process lessens the proportion of phosphorus in the iron, especially when the lime, either slaked or pulverised, is added immediately after the melting of the pig iron with the blast at a temperature of 40° C. Fined iron with an addition of 4½ lbs. of lime contained 0·02 per cent. of phosphorus, with an addition of 5½ lbs. of lime 0·013 to 0·017 per cent. of phosphorus, and with no such addition 0·022 to 0·023 per cent. of phosphorus.

Pig Iron for Use in Forges.—C. A. Jacobsson ‡ describes second-class pig iron in respect to its use in hearths and forges. Such a pig

* "*Ist die directe Darstellung von Schmiedbarem Eisen aller Art möglich?*" Leoben, 1890.

† *Jernkontorets Annaler*, vol. xlv. p. 321.

‡ *Wermländska Annaler*, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 453–459.

iron when used gives a bad slag and is difficult to manipulate. A pig iron suitable for use in the forge usually contains :—

Silicon.	Phosphorus.	Manganese.
0·5–0·7	0·02–0·10	0·0–0·4

sulphur, in any quantity, being very rarely present. If the percentage of either of these impurities is much higher than the above the metal is hard to work. Occasionally, however, this is not the case, and a second-class iron of good quality results. The operation usually requires great care and attention on the part of the workmen, and the dimensions of the hearth are of the utmost importance. It is necessary, too, to have a perfectly adequate quantity of slag in the hearth. This is best added at the commencement of the operation, and the operation itself must be in nowise hurried.

The weld iron thus produced varies very greatly in quality, withstanding but a very much lower heat in some cases than in others. This necessitates a more frequent reheating when rolling into bars. Such an iron is liable to have its edges crack or tear under the hammer, and this is due sometimes to the character of the metal and sometimes to having been wrongly treated in being reheated. The pig iron which produces this class of weld iron is the second quality metal to which the author refers.

The author then proceeds to examine the relative values for forge purposes of several varieties of pig iron of different composition. He instances, in the first case, one containing :—

Silicon.	Phosphorus.	Manganese.	Carbon.
0·8	0·12	0·3	Low

the fracture being mostly grey.

Practice has proved that such an iron is one of the most difficult to handle, as the high percentage of silicon causes red slags, a bad iron, and great loss. The manganese, which is also present, adds to the difficulty of the treatment. Its presence is always very disadvantageous to the working of the hearth, making the slag bad and the iron poor. The treatment it obliges is diametrically opposed to that which should be employed in order to favour the elimination of phosphorus, the consequence being that the phosphorus of the pig iron passes into the weld iron, and this is cold short.

The author next considers the value of a pig iron containing only about :—

Silicon.	Phosphorus.	Manganese.
0·5	0·05	0·15

The fracture is half white. The quality is a good second-class.

Such a metal is of very frequent occurrence, and may be treated in hearths without any particular precautions being taken. The treatment proceeds with regularity, the slag is good, as also is the metal produced, and there is but little loss of iron on hammering.

A third pig iron considered is one containing as a maximum the same percentages of silicon and manganese as those just mentioned, but with rather less phosphorus—0·03. The fracture is mottled. It closely resembles the last-described pig iron in working quality, but the metal produced is better, and the manganese being usually somewhat lower the work is easier and the slag of a lighter colour. It yields a soft bar iron, and the loss of metal is but small. It is therefore a second-class pig iron of a yet better quality than those previously described.

Finally, the author observes, there is another second quality pig iron which differs from these others in every respect, and is practically, if not absolutely, useless in a forge. The slag it yields is red, and its melting-point is low, causing a great loss of iron; the iron produced is of poor quality, and the consumption of fuel is very high. Indeed it is wanting in every quality which a pig iron should possess that is to be used for the production of malleable iron in hearths or forges. It contains 0·4 per cent. or upwards of manganese. The higher the percentage of manganese the worse will the metal be, the percentage of silicon appearing to be without any very marked influence provided it does not exceed 0·6 per cent. This variety of pig iron is usually white in fracture, and is of more common occurrence than might be supposed, being frequently made at furnaces which produce alternately forge pig iron and Bessemer pig iron.

With regard to the action of phosphorus, the author observes that it is a matter of common knowledge that it renders the malleable iron produced from it soft in the fire, and it must be heated to but a low temperature. It yields, however, a dense bar iron, free from cracks, if the phosphorus does not exceed 0·03 per cent. If the percentage of phosphorus in the pig iron reaches 0·06, the iron it yields becomes still more difficult to reheat, great care being required not to over-heat it, in which case the bars would split at the edges and tear. A pig iron with 0·08 of phosphorus is very similar to that with but 0·06 per cent. When the percentage reaches 0·12 or 0·14 the faggots require but a very short time to reach the complete welding heat, and they appear to increase in size under the influence of the furnace gases, especially as regards their section. The metal shows a number of cracks and tears along the edges on rolling, and a portion of the iron flows out, causing

considerable loss. This necessitates extreme care in bringing the metal up to welding heat.

Combined carbon acts in a very similar manner to phosphorus as regards susceptibility to heat; it may happen, therefore, that a good forge pig iron, free from phosphorus, may yet be difficult to reheat, and indeed the more so the higher is the percentage of carbon.

Having thus considered the quality and character of the pig iron which gives the best results in the forge or hearth, the author next proceeds to discuss these furnaces themselves, giving details as to their dimensions, and as to their working results. He compares in this latter respect—(1) A double hearth; (2) an ordinary hearth with two tuyeres; and (3) an ordinary hearth with one tuyere. The double hearth gave the best results, the hearth with one tuyere the worst.

Referring to the variations in the dimensions of a hearth, rendered necessary by the character of the pig iron to be treated, the author gives those he would adopt in the construction of an ordinary hearth with two tuyeres in the case of each of the four varieties of pig iron to which attention has already been drawn. The heating furnaces to be employed are also considered, as also is the temperature of the blast. With regard to this latter, if the temperature is raised to 150° or 200°, the author's experience shows a saving to be effected in the consumption of charcoal of about 5 per cent.; and this is increased to about 11 per cent. if the temperature of the blast used is raised to 250° C. The use of peat, sawdust, or other uncoked material in admixture with the coal and charcoal used, also aids in cheapening the cost of the operation, but they must be perfectly air-dry. The author next compares the cost of various varieties of fuel used at works, and he shows that a higher or more regular heat in the reheating furnace, or a higher production, was never obtained than when a fuel mixture of the following composition was employed:—Equal parts of charcoal, peat, and wood shavings, with a quarter or half a part of bituminous coal. The author concludes his paper with some remarks relating to the use of regenerative furnaces for reheating purposes.

Experiments are described by J. P. Ranström,* who shows that a pig iron containing from 0·53 to 0·6 per cent. of manganese, and 0·01 to 0·015 per cent. of sulphur, always yielded a malleable iron which gave bad results on smithing. Modifications in the furnace charges led to the production of a pig iron with less manganese—0·23 per cent.—the sulphur remaining at 0·01. This pig iron gave a wrought iron of

* *Jernkonterets Annaler*, vol. xlv. p. 319.

good quality. It would thus seem that in the case of weld iron 0·5 to 0·6 per cent. of manganese is equivalent in its action to that of a high percentage of sulphur.

Pile for Manufacturing Bar Iron.—Mr. W. P. Hopkins * has devised a method for making refined guide iron which consists in rolling the puddled ball direct into channels, piling these on one another, and then filling the interstices with waste scrap iron. The pile thus formed is reheated to a welding temperature, and then rolled to the desired shape.

The Lash-Johnson Direct Process.—In this process the ore and the reducing agent are crushed separately to a mesh size of $\frac{1}{4}$ inch. Then about 20 to 30 per cent. of the reducing agent is added to the ore, and the two ground together until both are in the state of fine powder. During this grinding a binding material is added, such as sodium silicate or tar. The dried and caked mass is then spread over the hearth of a reverberatory and subjected to the action of a reducing flame. The material hardens, and is then broken into irregular masses by a bar, thus allowing a better penetration of the heat. A covering consisting of two-thirds powdered glass and one-third carbon is then scattered over the charge. As soon as the slag become fluid it is tapped off, resulting in the elimination of much of the phosphorus. It is claimed that by this process an iron of any desired percentage of carbon may be obtained.†

* *Iron Age*, vol. xlvi. p. 841, two illustrations.
† *Ibid.*, vol. xlvii. p. 141.

FORGE AND MILL MACHINERY.

Rolls for Hot-Piling Puddled Bars.—Illustrations are given in *Iron* * of the cutting and piling rolls designed by Mr. R. R. Gubbins. A pair of rolls, each of which carries a strong obtuse cutting blade, are mounted in housings in line with the puddled bar rolls, and are driven by them. The bar, after rolling, is at once passed between these rolls, and is nearly cut through at equal distances on opposite sides, so that it can be folded backwards and forwards into a pile after the requisite number of sections have been cut off in a hot shears. These piles can readily be brought up to welding heat, and their original heat is thus saved.

New Blooming Mill.—A full plate illustration of the 15-inch three-high blooming mill at the works of the Lackawanna Iron and Coal Company, Scranton, Pennsylvania, is given in *Engineering.*† A plan, elevation and cross section of the mill, and a plan of the works, are given. The mill is employed for rolling down ingots to 7 inches square and 8-inch blooms, and to billets 4 inches square. The ingots are received on the rollers fed through the lower rolls to the catching table, which feeds them back to the upper pass. The main engines are vertical, with cylinders 48 by 40 inches, and run at sixty revolutions. A small engine with 8-inch by 12-inch cylinders is used to run the rollers on the table and catching table. The latter table is carried by counterbalanced bell crank levers, which are pulled over by a hydraulic ram, so as to raise the table.

Rolling Sheets.—R. M. Daelen ‡ discusses the relative values of three-high and two-high rolls in rolling sheets, and publishes drawings of the Lauth train. In rolling bars on a three-high train the middle roll generally has a fixed bearing, so that it takes the pressure alternately above and below. But with sheet rolls their diameter must be

* Vol. xxxvi. pp. 354–356. † Vol. li. pp. 101-102.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, through *Iron Age*, vol. xlvii. p. 55.

made large, so that there is not room enough to give the bearings sufficient strength. This led Lauth to the idea of so arranging the middle roll that it touches the upper and the lower roll alternately, so that their bearings alone take the pressure. This made it possible to make the diameter of the middle roll smaller than that of the others, and incidentally lessened the height to which the material to be rolled had to be lifted. The author questions whether there are any other advantages in practice, because the wear of the surface is greater as the diameter of the rolls increases. The uneven extension of the material between two rolls differing in diameter cannot be considered advantageous under all circumstances, many rolling-mill men being convinced of the contrary, so far as working steel is concerned. These reasons have led to the abandonment of the Lauth three-high train for the manufacture of high-grade boiler plates, or have led to a modification of the design by making the middle roll as large as the others. The author cites as the largest Lauth mill for heavy gauge plates on the Continent, a mill bearing 35·4-inch and 17·7-inch rolls, 134 inches wide. The middle roll is mechanically raised and lowered after every pass, an arrangement which is used generally, with the exception of fine sheet mills, and even with them it might prove advantageous, because it prevents the shock which otherwise occurs when the sheet enters between the lower and the middle roll. Latterly universal mills have been successfully introduced in the Lauth system, in which cases it is generally sufficient to place the vertical rolls only on one side of the housings. The author examines in detail the working of a mill having the following dimensions:—

	Inches.
Length of rolls	59·0
Diameter of upper and lower rolls	23·6
Diameter of middle roll	15·7
Diameter of bearing, upper and lower rolls	15·7
Diameter of bearing middle roll	11·0
Length of bearings	13·4

Assuming that the middle and upper rolls are driven by the lower roll, the maximum distance between the axis of the upper and lower rolls is 40·4 inches. Experience has taught that slabs thicker than 0·98 inch are not carried through.

Taking specific data, let it be assumed that sheets 47·2 inches wide and 0·039 inch gauge are to be rolled. The slabs, with a maximum thickness of 0·98 inch, the usual width of 5·19 inches and 48·4 inches length, would weigh 80·25 lbs. Counting 20 per cent. for waste and shearing, the weight of the sheet is 64·15 lbs., which for a width of

47·2 inches, and 0·039 inch of gauge, makes the length 122·4 inches. This, therefore, defines the maximum size for such a train.

The capacity of a three-high train is very large. A three-high train can roll down to 0·047 inch gauge, and assuming that higher gauge sheets are to be produced, the three-high train, in such a case, needs two finishing trains, since its product cannot be finished in one set in the same time, in rolling fine sheets. These three sets call for a 100 to 120 horse-power engine, while the two-high train, with one finishing set, needs only 80 horse-power. The speed is about fifty revolutions per minute in both cases, and the crew in both cases is one roller, one helper, one man at the spindle, one boy, one heater, and under certain circumstances, one doubler. This crew can roll in a 12-hour turn, on a three-high train with two heating furnaces of the ordinary design, 6 to 7 tons of slabs, averaging 22 lbs. Counting two hours' time lost, the capacity is sixty to seventy per hour. A two-high train can only handle forty, or two-thirds, but even this capacity is possible only for certain gauges. As soon as the roughing has been done, the difference between the two systems appears, since the finishing work differs considerably. On a two-high train the same crew which has done tho roughing does the finishing, while for the three-high there must be at least one extra crew exclusively on finishing. At least two heating furnaces are called for. As soon as the finishing becomes more difficult, on account of the doubling, and needs more care in heating, as it does for larger sheets and smaller gauges, then one crew cannot finish as quickly as the material is delivered by the roughing, and the latter is naturally reduced in capacity. This relation between roughing and finishing becomes more disadvantageous with one crew on a two-high train as the gauge of the sheets grows smaller. The work on the three-high train is not influenced, since the second crew takes the product, and the work on the train is not hampered. Of course it is quite another question whether the finishing crew can handle the product. If it accumulates, matters must be so arranged that the train is given work of a character which the finishers can put through faster than the roughers. This is rarely possible, and it has been assumed, therefore, that one three-high train calls for two finishing trains with their two crews and four heating furnaces. The advantage of the three-high system does not therefore lie in the system itself, but in the organisation of labour which it involves. Three crews working on two-high trains will turn out at least as much. But the number of sets must be six, or double that of the three-high system, which involves

increased power, a greater quantity of lubricants, and greater attendance.

Thus the examination leads to peculiar results, so far as the manufacture of thin sheets is concerned. The finishing work predominates to such a degree that the value of rapid roughing is nearly lost. With two-high trains it is necessarily hampered; with the three-high system so many additional crews are called for that the finishing work sacrifices the advantages gained in roughing. In rolling thin sheets, therefore, the advantage of three-high work does not consist in increasing the production, but in economy of power, of materials, in labour, and in capital account of interest.

A full utilisation of the three-high system, which is kept in narrow bounds by the plan of carrying along the middle and upper rolls by friction, seems attainable only by driving the upper roll by gearing. If the gearing is used long slabs up to 2·36 inches may be rolled. With rolls 59 inches long sheets trimming down to 55 inches may be easily rolled. The slabs are made 57 inches long, and with a width of 6 inches and 2·36 inches thick, they weigh 227 lbs. apiece. The trimmed sheet rolled from it weighs about 194 lbs., and with a length of 158 inches is 0·08 inch thick.

Another consideration makes it desirable to drive the upper roll. When only the lower roll is driven, and the other two are operated by friction, the latter should theoretically develop along the whole line of contact. As a matter of fact, however, the lower and middle rolls wear quite rapidly, especially in the centre. This drawback is felt more with short rolls, and the result is that the friction decreases and that the middle roll develops a tendency to stand still, so that the slab does not go through the pass between the middle and the upper roll. The result has been that in practice long rolls have superseded short ones in three-high trains, even if the width of the sheets to be rolled does not require it. It might be possible to attain the same end by enlarging the middle roll, but that would partly sacrifice the chief advantage of the system—its ability to roll rapidly. Thus the smaller of two evils has been chosen, and 47·2 inches has become the minimum width of rolls, even for narrow sheets. An effort has been made to resist the rapid wear of the rolls by allowing water to flow upon them during rolling, thus loosening the scale from the sheets; but this has the disadvantage of rapidly cooling the slabs and diminishing the speed of rolling. Thus it would appear that every effort to adapt the three-high system to thin sheets, which are usually

narrow and short, is met by drawbacks. When the three-high train is arranged with driven upper roll for thin sheets, the disadvantages alluded to disappear. But with a train so arranged it is not possible to roll down below 0·12 inch, because the gears touch. For the finishing of thin sheets, however, roughing down to 0·12 inch possesses only doubtful value, because doubling cannot begin.

Criticising this review a writer in the *Iron Age* points out that the author has not taken into consideration the most important point in the manufacture of thin sheets—the uniformity of gauge of any individual sheet. Specifications of manufacturers of hollow ware and stamped goods provide for a maximum variation of 5 per cent. above and below. The slabs for thin sheets are roughed down as far as possible, down to 0·02 inch, and then doubling is resorted to, once, twice, or three times. After every doubling they are reheated. In order to obtain a product of uniform gauge, the product of the roughing must be as uniform as possible. The writer holds that the three-high trains yield a product which very often does not come up to this requirement, and at times produces a large quantity of seconds.

When well conducted, rolling on two-high trains will allow of bringing down the wasters to 4 per cent., even with thin sheets. For sheets under 0·02 inch three-high trains are not well adapted, and certainly make three and even four times the amount of wasters. The writer, therefore, concludes that the Lauth system is not suitable for thin sheets.

New Bar Mill.—A new bar mill has recently been erected at the Milwaukee works of the Illinois Steel Company. It has a 9-inch train, consisting of five stands of housings. Three sets of rolls are three-high; there is one set of oval rolls, and one of finishing rolls. The three-high sets are made with closed tops, having brass centre-screw box, steel screws, and bronze journal bearings. The oval and finishing sets have open tops with spring carriers for the upper roll, thus doing away with liners when rolling different thicknesses of flats, the spring bringing the upper roll into proper position when the bolts are slackened. The pinions of the train are also open-tops, with Hunter's self-oiling bearings. A Smythe-Laughlin regenerative furnace is used, 14 feet in length from bridge to bridge, and 7 feet from wall to wall, with four doors.*

* *Iron Age*, vol. xlvii. p. 183.

Rolling-Mill Feed Table.—A table of this kind is illustrated in the *Iron Age.** It is designed by Mr. J. R. George, and is arranged to be raised and lowered from above, so as to overcome the difficulties met with in the ordinary inverse method. The whole of the machinery is rendered easily accessible, and it is claimed that all bearings are so placed that they can readily be kept in line and lubricated, an item of importance where heavy tables have to be raised and lowered from 2 to 3 feet some 200 times in the hour. The first cost of the plant is also less.

Rolling-Mill Engines.—Illustrations are given in *Industries* † of a pair of coupled rolling-mill engines. The diameter of each cylinder is 42 inches, and stroke 5 feet. Piston valves are used, and the link motion is driven by a separate engine. Dimensions of the chief parts are given.

The *Iron Age* ‡ publishes drawings of what is stated to be the largest horizontal engine fitted with Corliss liberating gear. It is intended for the new beam train now being erected at the Homestead Steelworks. The engine has been designed and constructed by Messrs. Robert Wetherill & Co., of Chester, Pennsylvania, and has a 54-inch cylinder with 72-inch stroke, and develops 3500 horse-power. The bed-plate is of the Tangye type, having the pillar block cast in the bed. The main shaft is an open-hearth steel casting, 27 inches in diameter in the journals and 30 inches in the wheel. The journals are 48 inches in length, and are provided at either side of the shaft with adjustable wedges and screws.

Power is transmitted directly from the outboard end of the engine shaft to the rolls by means of clutch couplings, which are standard open-hearth steel castings. The balance wheel is 27 feet in diameter, and weighs 180,000 lbs. It is made in segments planed and fitted together, with the centres forced on the main shaft, the segments being secured with turned bolts and forged links shrunk on. The crank disc is 9 feet 4 inches in diameter, and the crank pin 16 inches. The guide surfaces are cast independent of the bed, and are bolted on. The crosshead is an open-hearth steel casting, with a pin of forged steel forced in.

For closing the steam valves vacuum pots are used, mounted on brackets secured to the steam cylinder. All levers are double-armed thus avoiding overhanging joins.

* Vol. xlvii. p. 194. † Vol. x. pp. 392 and 396.
‡ Vol. xlvi. p. 1080, with supplementary sheet of drawings.

The new plate-rolling mill * of the Krupp Steelworks at Essen is of the reversing type, with cylinders of 51 inches, and with a stroke of 41 inches. The rolling mill is intended for armour-plate of the largest size.

Hydraulic Mill Appliances.—In a paper read before the Engineers' Society of Western Pennsylvania, Mr. C. Hyde † discusses various hydraulic mill appliances, such as feed-tables and appliances for stripping the mould from the ingot. Drawings are given of such arrangements, various modifications of which are described.

Shear Table.—A shear table, designed by Mr. H. Aiken,‡ is so constructed that the metal is fed to the shears by a positive pushing action, thus admitting of the accurate cutting of the metal into pieces of definite length, without requiring much manual labour. Provision is also made for turning the piece on the table, and for gauging the length of the pieces cut. The description of the arrangement is accompanied by several illustrations.

Toggle-Joint Drawing Press.—A press of this description is illustrated in the *Iron Age*.§ It weighs 58 tons, and is designed for very deep and heavy drawn material. The length of the blank-holder stroke is 22 inches; the length of punch stroke, 36 inches; adjustments of blank-holder and punch, 14 inches; distance between uprights, 73 inches; bottom of blank-holder slide, 60 by 60 inches; distance from bed to bottom of outer slide, when the slide and adjustment are raised, 53 inches; the largest blank, 60 inches; the largest punch for deep work, 36 inches, and for depths not exceeding one-sixth of the punch stroke, 48 inches; size of the flywheels, 38 by 6 inches; speed of flywheels, 250 revolutions; proportion of gearing, 1 to 63; strokes per minute, 4; diameter of large gears, 109 inches; floor space 114 by 115 inches; and the extreme height, 18 feet.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 530.
† *Iron Age*, vol. xlvii. pp. 420–421.
‡ *Ibid.*, vol. xlvi. pp. 944–945.
§ Vol. xlvi. pp. 629–630, one illustration.

PRODUCTION OF STEEL.

CONTENTS.

I.—*THE OPEN-HEARTH PROCESS.*

Open-Hearth Steel Furnaces.—Mr. B. H. Thwaite * states that the actual nett useful thermal efficiency of a modern open-hearth steel furnace does not exceed 5·8 per cent. Yet the average modern open-hearth is a decided improvement upon the puddling furnace, the nett useful thermic efficiency of which is only from 1·2 up to 2 per cent. The author then examines the causes of the wastefulness of most steel furnaces, and gives rules for their improvement. As the result of a thorough examination of the subject, it is laid down that the desirable characteristics of a steel furnace deduced from the results of thermic calculations may be enumerated as follows:—(1.) The producer shall satisfy the requirements enunciated in the best known equation of efficiency. (2.) The proportion of the hydro-carbons contained in the original fuel should be repeated as nearly as possible in the combustible gases produced therefrom. (3.) The connecting conduit or flues between the furnace should be constructed as recommended, and be as short as the good order of working will admit. (4.) The gas reversal valve should be disconnected from the chimney flue, the valves should be of the mushroom type, and of low carbon steel. (5.) The gas regenerator chamber, as arranged at present, should be abandoned, the gas conduit or flue being connected direct to an air and gas mixing chamber built at each end of the furnace hearth. (6.)

* Paper read before the South Staffordshire Institute of Iron and Steel Works Managers; *Colliery Guardian*, vol. lxi. p. 280.

The air regenerators should be composed of separate and distinctive chambers, encased externally with iron plates, and should have a capacity equal to that of the present gas and air chambers combined. (7.) The air regenerator chambers should be preferably built bodily over or alongside the furnace gas and air mixing chambers. (8.) The expended thermo-chemical gas escape chimney should be connected directly to the upper part of the body of the air reversal valve. (9.) The air supply to the furnace should be supplied by a positive fan or blower, to exhaust or force its supply through a jacket surrounding the regenerator vessel. With reference to the third characteristic, the construction recommended is that the producer plant and the steel plant shall be sufficiently near to each other as to avoid a greater reduction of sensible temperature than 10 per cent., and also that if the gas conduits pass along damp ground they shall be lined externally with concrete.

H. Schonwälder * publishes illustrations of an open-hearth furnace with a modified arrangement of the regenerator chambers. Each of the four chambers, as usually employed, is divided by a partition, so that instead of four chambers there are eight.

A Calorimetric Study of the Open-Hearth Furnace.—G. Desprit † discusses the reactions which occur in the Siemens furnace as modified by Biedermann and Harvey. In this form the spent gas is partly returned to the producer and regenerated. The composition of the producer gas and of the spent gas is given, and also the amount of oxygen required for combustion. The spent gas, when it is returned to the producer, contains a certain amount of sensible heat, and its carbonic anhydride contains carbon which is capable of regeneration to the extent of 38 per cent. of the combustible, which is accordingly supplied free of cost. Further, these gases contain hydrogen, which brings the economy up to 43 per cent. In the old system the spent gases escaped to the chimney at about 300° C., but when they are carried back to the producer the author considers there is a saving of about 6¼ per cent. of the total heat generated. This leads to a considerable saving in labour and other details. When a reducing atmosphere is used in the furnace, the carbonic oxide, which would ordinarily be wasted, is saved by the means here employed. When limestone is used in the furnace there is a further economy due to the carbonic

* *Stahl und Eisen*, vol. xi. p. 386.

† *Revue Universelle des Mines et de la Métallurgie*, vol. xi. p. 246.

anhydride given off by its decomposition. This process cannot, of course, go on indefinitely, as the real restorer of heat is the oxygen, and this cannot be reduced to too great an extent. Within the limits given by the author it is considered that the gases supplied from the producer may have a temperature of 700° C.

Defects in Open-Hearth Furnaces.—Some defects in the design of open-hearth steel-melting furnaces are enumerated by Mr. H. D. Hibbard * as follows:—Gas or air ports and ducts too few or too small; regenerators too small; checquer-work too closely piled; flues and stack too small; working hearth at too low a level; gas and air ports beside each other; regenerators in which the draught is horizontal; too thin walls and brickwork; use of clay bricks; circular hearths; and furnace with ends unlike. When the ports or ducts are too small, or not properly placed, the air and the gas cannot have proper ingress, nor can they be evenly distributed, and the products of combustion cannot get away sufficiently easily. The proper relation in the size of the air and gas ports is also an important feature, as on it depends the equivalent supply of gas and air. When the regenerators are too small, heat and accordingly fuel is wasted, also the flames pass right through the brickwork and injure the valves. Too large producers are hardly likely to be built. Checquer-work, too closely piled, is often used to counteract the faults of small regenerators, but as the passages for the gases are small the flow is unduly impeded, especially when there is much dust. In consequence of the accumulation of dust, and the slagging due to it, the regenerators have to be shut down more frequently. Similarly, the flues are likely to be choked if they are too small, and an insufficiently sized stack will not give a good draught. Working the hearth at too low a level means that gas has to be drawn into the furnace, so that air will leak in at the same time and cause a waste of iron.

Gas and air ports beside one another, or arranged so as not to bring the air into the working chamber above the gas, are to be avoided. The air should be brought in above the gas, so as to depress the flame on to the charge, and to avoid oxidising conditions. Horizontal regenerators, or those in which the air has a horizontal course, are not efficacious, as the hot air tends to flow along the top while the cold air remains at the bottom. In these, therefore, heat is not properly trans-

* Paper read before the Engineers' Society of Western Pennsylvania; *American Manufacturer*, vol. xlviii. No. 7, p. 136.

ferred to the incoming air or gas. Too thin walls or brickwork permit much radiation of heat, and clay bricks are not economical. In circular hearths the flame does not spread as at first expected, but passes straight through the chamber. A furnace with its ends unlike is of course very rare; it gives trouble from the difference of draught in the two ends. The proof of a good furnace is of course its record in the hands of competent men; and one which has melted 500 heats at a fair rate, and with good economy of fuel, ought to be altered with extreme caution, if at all.

Manufacture of Basic Open-Hearth Steel.—A description of the manufacture of open-hearth basic steel at the Parkgate Iron and Steel Works is given by Mr. J. Davis.* The pig iron used contains:—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
2·5	0·357	0·042	2·63	1·68

At these works are two 20-ton furnaces for making basic steel, and run nine or sometimes ten charges per week, producing 145 to 175 tons of ingots.

The furnaces are arranged in a line, the charging platform on one side being a sufficient distance above the floor of the works to admit the casting ladle and carriage, which runs on rails over a pit parallel to the furnace. Each furnace is provided with a separate chimney, and with double-faced mushroom valves and regenerator chambers of large capacity, but similar in construction to the most modern forms. With such chambers a basic furnace has been working twelve months without changing the checquer-work. The furnace proper is composed of two wrought iron sides, supported by double-headed rails and H iron buck staves well braced together. The bottom is built up of cast iron plates supported on H iron girders. The brickwork is built in the usual manner, only instead of using best silica bricks for lining from the bottom up to the level of the fireplates, ordinary firebrick will do. Then, as a separator, just above the slag-line, a chrome brick course is built in all round the lining.

The bottom is made of well-burnt dolomite mixed with tar and rammed in with hot irons, and is finished off by raising the temperature and filling in with dry lime. The charge consists of 75 per cent. of pig iron, and 25 per cent. of scrap, preferably all steel. Ore is charged till the fracture of the sample is satisfactory. The slag is kept

* Paper read before the Cleveland Institution of Engineers. *The Colliery Guardian*, vol. lx. p. 103. Compare *Journal of the Iron and Steel Institute*, 1890, No. II. p. 786.

as basic as possible, and is all retained in the furnace till the end of the operation, so that the furnace must be larger than an acid furnace. It contains 13 to 15 per cent. of phosphorus. Two Wilson 8-cwt. producers are used for each furnace, and the consumption of fuel is 11 cwts. of slack per ton of ingots. This includes the fuel used over Sundays and for heating up. A charge of 14 tons of basic pig iron and 5 tons of scrap was worked with 42 to 48 cwts. of pottery mine and 53 to 60 cwts. of limestone.

The author prefers limestone to lime—(1) Because there is no lime dust to act upon the silica lining and blocks, which tends to fuse the face of the bricks, thus causing the lining to wear more rapidly; (2.) there is no dust to be carried away by the draught into the checquers, and by using limestone the checquers will run for twelve months without changing; (3) it is less expensive.

The following account of a charge is fairly typical of Parkgate working. Furnace charged 4.30 A.M. and tapped 1.30 P.M., working 9½ hours. The charge was poured into the following sized ingots:—One 5 tons, the remainder into ingots weighing from 2½ to 1 ton each. The 5-ton ingot was cogged into a slab 34 inches by 8 inches, and rolled into a plate 30 feet long, 3 feet 6 inches wide, and 1 inch thick. The other ingots were cogged and rolled into plates ⅞ inch and ¾ inch various sizes. The annexed table gives the chemical analysis and mechanical properties of the above-mentioned metal:—

Analysis.		Dimensions of Test-piece.			Breaking Strain.		Extension on 8 Inches. Per cent.
		Width.	Thickness.	Area.	On Piece.	Square Inch.	
					Tons.	Tons.	
Carbon	0·150	0·98	0·98	0·36	28·1	29·27	22
Silicon	trace	0·98	0·89	0·87	25·0	28·73	24
Sulphur	0·043	0·98	0·74	0·72	20·2	28·00	28
Phosphorus	0·060	1·47	0·68	0·99	29·2	29·50	24
Manganese	0·600	...	...	...	...	...	...

Remarks.—Cold and tempered; bends good.

The reason why the ¾-inch plate had a lower tensile strength than the 1-inch plate was that the former were rolled much smaller and therefore finished at a greater heat. The repairs to the hearth after tapping are made with ground dry basic slag. In some instances basic slag mixed with tar is used. The repairs are generally required round the slag line; this is soon done, and the furnace ready for charging.

To get the results referred to, the author generally uses about 3 cwts. of low silicon hæmatite pig, so that the metal is reboiled just as in working the acid process.

Results are given of tests made from plates suitable for ship and bridge work to pass requirements of 28 to 32 tons per square inch; also results of tests for ordinary boiler requirements of 26 to 30 tons per square inch, and in a further table tests made on steel for locomotive and boiler tubes or any welding quality, or plates exposed to flame which may be required to stand 21 to 25 tons per square inch, or 24 to 28 tons, thus passing Admiralty requirements for tube purposes.

From his own experience, the author avers that basic steel can be made uniform and solid. As regards the best form of furnace it would seem preferable to use a 20-ton Hilton furnace, which is a rectangular furnace cased with iron and supported on columns, so that the bottom is kept cool. These furnaces have worked for twenty-four weeks without repair, and were then only stopped to clear out the regenerators.

The Norristown Steelworks, Pennsylvania.—This new works possesses two 15-ton open-hearth furnaces, a rolling-mill with a pair of reversing engines of 1500 horse-power, and a 20-ton travelling crane. The weekly capacity of the new plant is estimated at about 500 tons of ingots. It is anticipated that the works will be started during the present summer.*

Basic Steel in Alabama.—Mr. W. H. Hassinger,† in referring to the iron ore districts of the Southern United States, gives the following partial analyses of the pig iron produced in this district:—

Grade.	Silicon.	Sulphur.
	Per Cent.	Per Cent.
No. 1 foundry	3·12	0·022
No. 2 foundry	3·00	0·030
No. 3 foundry	2·55	0·020
No. 1 soft	3·65	0·014
No. 2 soft	4·14	0·013
No. 1 silver grey	4·50	0·012
No. 2 silver grey	4·85	0·010
Grey forge	1·93	0·070
Mottled	1·26	0·097
White	0·84	0·289

Phosphorus from 0·57 to 0·64 per cent.

* *Iron Age*, vol. xlvi. p. 989.

† *Ibid.*, vol. xlvii. pp. 237–238.

To make such a pig iron as this suitable for the basic process, it would be necessary to lower the percentage of the silicon present. The sulphur is also high. The elimination of the sulphur in the blast furnace leads to the production of a pig iron higher in silicon, and the author concludes that the best method of procedure to adopt would be to give a preliminary short blow to the metal leaving the cupola for the purpose of eliminating the silicon.

At Birmingham, Alabama, a 13-ton basic open-hearth is in successful employment. It has magnesite brick sides and bottom and a silica roof, the ordinary dolomite bed having been abandoned after trial owing to the highly siliceous character of the charge. The bottom is made of calcined magnesite, and but little furnace repairs are found necessary. The daily outturn of the furnace is from 25 to 30 tons; this could be increased considerably but for the difficulty experienced in casting into the small ingot moulds that have to be employed owing to the absence of a blooming train. These moulds have the dimensions 6 by 14 inches.

A test-heat made in this furnace consisted of:—

	Lbs.
White pig iron, 0·68 phosphorus	15,000
Pit scrap from former heats	5,525
Wrought scrap	4,514
Brown ore, 55 per cent. of iron	1,300
Limestone	2,900
Spiegeleisen	200
Ferro-manganese	200
Total metal	25,439

The charge resulted in:—

	Lbs.
Steel, 24 ingots	22,550
Pit scrap	1,510
Total metal	24,060

showing a loss of about 6 per cent. The slag is not tapped at the end of the heat, but a small addition of fluorspar is made.

The steel made contained:—

Carbon.	Manganese.	Silicon.	Phosphorus.	Sulphur.
0·08	0·29	trace	0·018	0·066

The tensile tests showed:—

Tensile strength, lbs. per square inch	48,660
Elastic limit, lbs. per square inch	32,275
Elongation, per cent.	28·0
Contraction, per cent.	57·4

The cost of production of this steel is 21·23 dollars per ton, about 10·75 dollars above the cost of pig iron. The cost of acid steel at Pittsburgh is said to be 43 dollars.

II.—*THE BESSEMER PROCESS.*

Bessemer and Open-Hearth Metal from the Same Ores.—According to Stahl,* there is as yet little evidence to show whether Bessemer or open-hearth metal made from the same ores is the better. For steel of the finest quality, the same raw material is rarely used for the two processes. At the Fagersta Works it is found, however, that manufacturers prefer the open-hearth steel to the Bessemer product, more especially in the case of high-carbon steels. With regard to the production of the mildest ingot metal, this preference for open-hearth steel can be understood, as metal can be made with less than 0·1 per cent. of carbon. This is, however, difficult to do in the case of the Bessemer process, if the ordinary Bessemer pig iron is used.

With the same ores, the percentage of phosphorus is lower in open-hearth metal than in the Bessemer product, as with the same quantity of fuel the outturn of open-hearth pig iron is greater than that of Bessemer pig iron. It is probable, also, that the higher percentage of nitrogen in Bessemer steel has some influence on the question.

The Cost of Bessemer Steel.—The *Iron Age* † publishes the following estimate of the cost of production of Bessemer steel based upon actual figures relating to a year's work in the Pittsburgh Wheeling District:—

Converting.

	Dollars.
Pig iron	16.00
Loss, 15·25 per cent.	2.44
Labour	1.75
Ingot moulds and stoves	0.40
Manganese, refractory material, limestone, and fuel	2.50
Cost of ingots	23.09

* *Wermländska Annaler; Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 439.
† Vol. xlvii. p. 16.

Blooming.

Ingots	23.09
Labour	1.10
Fuel	0.75
Maintenance and repairs	0.25
Cost of 4 by 4 inch billets	25.19

This estimate, it will be seen, is based upon a price of 16 dollars per ton for the pig iron, a somewhat low cost for the majority of works in this district, which have to purchase their iron in the open market.

The Steel Industry of the North of Spain.—F. Gáscue * publishes a series of articles on this subject. After glancing historically at the rapid progress made by steel in recent years, both as replacing iron, and from a metallurgical point of view, he points out that in Spain two Bessemer converters and three open-hearths have been erected at Bilbao, and two open-hearths at La Felguera in Asturias. In addition other open-hearth furnaces have been erected at Elgoibar and elsewhere. The author's remarks refer only to Asturias and Biscaya, as these are the provinces of Spain which are best suited to the rise of an important steel industry, partly on account of the deposits of iron ore and coal, and partly owing to facilities for transport.

With regard to the ore, non-phosphoric iron ore has been found at several places in Asturias, but either not in large quantity or else in places where transport is accomplished with difficulty.

Iron ore deposits occur in Asturias in the Devonian formation. They vary from 27 inches to 6·5 feet in thickness. The number of these superimposed beds is usually six, but they are not always of workable thickness. At Quiros the ore is mined by open workings, but usually deep mining is employed. The ore exists in large quantity, but it contains a considerable amount of phosphorus.

With regard to the cost of production of pig iron, the author observes that Adaro has estimated the inclusive mining costs of the ton of ore at Quiros at 2s. 1d., delivered by rail at adjacent blast furnaces. The ironworks at Mieres obtains its ore from the Naranco Mine, the cost of mining the ton of ore being 2s. 1d., and of transport to the furnaces 2s. 3½d., being a total cost as delivered of 4s. 4½d. At the Casteñado mines the mining conditions are almost as favourable as they are at the Quiros mines.

From a general consideration of the cost of mining in various parts

* *Revista Minera*, vol. xli. pp. 35–38, 49–52, 65–67, 105–109, and 117–124.

of the province, together with transport charges, the author draws the following conclusions:—(1) Blast furnaces erected at Quiros could obtain ore at an inclusive cost of 2s. per ton; (2) others erected at Gijon at from 6s. 8d. to 7s. 6d. per ton; and others at Mieres and Langreo at from 6s. 8d. to 8s. 9d. per ton, the ore averaging 50 per cent. of iron.

As to the presence of coal suitable for the manufacture of blast-furnace coke, the coals of the Mieres Valley are well adapted for this purpose. Their yield is about 64 per cent. The cost of manufacture of the ton of coke at the Mieres Ironworks amounts to 11s. 4¼d., of which 10s. 4¾d. represents the first cost of the coal. The author believes it would be possible to reduce the cost of the ton of coke to 10s. 8¾d. if the coke-ovens were of a more improved type. The cost of transport to Gijon is 3s. 3d. per ton. At Quiros the cost would be about 13s. 6½d.

The manufacture of pig iron at Bilbao is then considered by the author, who estimates the cost of the ton of metal at from 40s. 2d. to 44s. 2d. In Asturias his estimates place the cost of non-phosphoric pig iron at 50s. 7d. at Quiros, 48s. 7d. at Gijon, and 48s. 1d. in the Mieres and Langreo valleys, or as low as 45s. for phosphoric iron.

The author next proceeds to discuss the future of the Bessemer and open-hearth steel industry in Spain. He refers to the Bessemer industry of Bilbao, where he observes that at the Altos Hornos Works there are two converters making fifteen blows in twelve hours, each blow yielding 8 tons of ingots. Unfortunately the great difficulty that new industries have to contend with in Spain is the want of a suitable market for the product. The manufacture of Bessemer rails has recently been commenced, and this industry has a hopeful future.

The author estimates the cost of manufacture at Bilbao the ton of Bessemer steel ingots at 74·38 pesetas (£2, 19s. 4d.). In Asturias the cost would, he considers, be about 82 pesetas (£3, 5s. 7d.). Labour is somewhat cheaper in Asturias than it is at Bilbao, and good refractory materials are also available at a slightly lower cost. The basic Bessemer process would probably be less successful in Asturias than the acid process, for although there is a greater abundance of phosphoric ore, yet the percentage of phosphorus is, as a rule, relatively low, the ore from Llumeres, which is richest in phosphorus, containing but 0·5 per cent. of that element.

The author next proceeds to compare generally the Bessemer and open-hearth processes. Of the three existing modifications of the

open-hearth process, the ore process would be most suitable for Asturias, ore being cheap but scrap dear. In the one process, however, the rapid boiling of the bath after the second or third addition of ore adds considerably to the wear and tear by corrosion of the furnace walls, and diminishes the duration of the campaign. In Spain the ore process, pure and simple, is nowhere employed, the rule being to use a considerable quantity of scrap, and only a little ore towards the end of the operation. At La Felguera, Asturias, the charge is usually 30 per cent. of pig iron, and 70 of soft scrap, together with 0·25 ton of ore for each 8 tons of ingots made. In 6½ working days 16 to 18 charges are worked off. This number, however, is reduced to 14 when the charge is 36 per cent. of pig iron, 64 of scrap, and 0·5 to 0·6 ton of ore, dephosphorisation taking place. A number of other charges are also given. The cost of the acid process at Bilbao is estimated at £3, 15s. 9d. per ton of ingot metal produced; in Asturias the cost would be about £4, 4s. 6d.

At the La Vizcaya Works there are two basic open-hearth furnaces. Here the management is obliged to purchase the whole of the soft scrap it requires. The author considered that the basic open-hearth process possesses considerable advantage over the acid process in Asturias, and calculates the cost of the ton of ingot metal produced at £3, 17s. 4d.

In his general conclusions the author observes that while Biscaya possesses, as compared with Asturias, a greater abundance of iron ore. Asturias, on the other hand, possesses supplies of fuel which fully equalise the disadvantage as regards iron ore. The basic Bessemer process is not likely to make much progress in Asturias, but the basic open-hearth process has good possibilities of success.

The Wellman Steelworks.—This works is situated at Thurlow, Pennsylvania. It possesses one blast furnace, 72 feet high and 17 feet in diameter at the boshes. There are two 15-ton open-hearth furnaces, two 3-ton Bessemer converters, a reversing blooming-mill with 30-inch rolls, a two-high plate-mill with 30-inch rolls, and a three-high mill with 25-inch rolls. A larger three-high mill is about to be added.*

A Pneumatic Accumulator for Use in Steelworks.—A pneumatic accumulator for hydraulic machinery, as used in the Bochum and other steelworks, is illustrated in *Stahl und Eisen.*† It is intended to reduce the danger due to shocks when working at high speeds, and this

* *Iron Age*, vol. xlvi. p. 524.

† Vol. xi. p. 132.

is done by replacing the ordinary dead weight or load in an accumulator by an air-buffer or compressor. In the form illustrated an air cylinder and plunger are placed above the water cylinder and plunger, and are connected by vertical columns. The areas of the air and water plungers are as ten to one, and the working pressure is 500 atmospheres in the largest now at work at Bochum. In this particular plant the air-plunger is 30 inches in diameter, and is connected to a series of six reservoirs 28 inches in diameter by 13 feet high. With these, there is a difference in pressure between the two ends of the stroke of less than 10 per cent. For low pressure work, such as cranes, both plungers may be of the same diameter. This device has been successfully in use for over a year, and larger plants are to be erected.

III.—*OTHER PROCESSES.*

Darby's Recarburising Process.—Mr. H. M. Howe * describes Darby's recarburising process as performed at an American works where the practice differs somewhat from that at Brymbo. Dry crushed Connellsville coke, in paper bags, each holding about 50 lbs., is thrown into the ladle along with the decarburised metal from the open-hearth furnace or the Bessemer converter, the first bag being thrown in as soon as the bottom of the ladle is well covered with metal. In the case of the converter, a little ferro-manganese is added before pouring the metal into the ladle. Tabulated results are given to show the accuracy attained. In twenty-four cases of open-hearth metal the carbon contents aimed at were within 0·15 to 0·17 per cent., and 0·28 to 0·31 per cent. In fifteen out of the twenty-four cases the carbon contained was within the limit, and in a single case only was it as much as 0·04 per cent. outside it. The results given for the Bessemer practice show a similar accuracy. The addition of coke-dust causes a violent reaction and a large flame, but the steel does not boil objectionably if the coke is well dried. Anthracite may be used with fair results. About half the carbon added is taken up by the metal, as compared with 85 per cent. of the gas carbon at Brymbo.

The Imperatori Process.—This process consists essentially in adding briquettes made of iron ore and coal to the bath of metal in

* *The Engineering and Mining Journal*, vol. li. p. 472.

the open-hearth process. Details of experiments are given, and it is stated that this process is one of considerable value.*

The Adams Direct Reduction Process.—This process,† as now employed at Pittsburgh at the works of Park Brothers & Co. in the manufacture of open-hearth steel, is fully described and illustrated in the *Iron Age*.‡ The first cost for the Adams plant, as applied to a 20-ton open-hearth furnace, is about £600 to £1000.

Drawings are given which show the construction of the furnaces now in use at the Black Diamond Works. Within the walls of the furnace are built four upright reducing chambers, arranged in two pairs set side by side. These chambers flare downwards from the top to the bottom, so as to permit of the easy withdrawal of the sponge and to prevent scaffolding. At opposite sides of each of the chambers are checquer-work chambers, which open into the reducing chamber, and are provided with horizontal partitions for the purpose of directing the gas backwards and forwards through the ore in horizontal passes, and for equalising the temperature of the gas. At the outer end of each of the reducing chambers is a gas inlet flue, at one end of which is a gas supply pipe, while the other end of the flue communicates with the checquer-work chamber. Each gas flue is provided with partitions, which cause the gas passing through it to travel in a circuitous course. On each side of the gas inlet flue is a draught flue. These draught flues at each end of the furnace communicate at one end with a stack flue and at the other end with the last checquer-work chamber of their respective reducing chambers. The draught flues are provided with air inlets controlled by valves, through which air may be admitted to burn with the waste combustible gas. Each of the reducing chambers has a hopper at its top for the introduction of a charge of ore, and these hoppers are closed by suitable doors or valves in order to exclude air from the chambers during the reduction of the ore. At the bases of the chambers are metal doors lined with fire-brick, which are so pivoted as to serve as drop bottoms. Below the chambers is a metal shoot to receive the sponge from the reducing chambers prior to its passage into the open-hearth furnace, into which a graphite conduit leads. The top of this conduit is closed by a fire-clay tile damper, which prevents the radiation of heat from the furnace. In the operation of the apparatus, all the reducing chambers may be used

* *Iron Age*, vol. xlvii. p. 781.

† See *Journal of the Iron and Steel Institute*, 1890, No. ii. p. 766.

‡ Vol. xlvi. pp. 835–837.

at once, or any one or more of them separately from the others. There are four chambers set above the open-hearth, and surrounded by the necessary arrangements for saturating the ore with heated natural gas, while excluding the air. Into these chambers the ore is charged in quantities sufficient for a single heat in the open-hearth furnace, the time of charging being so regulated as to insure a thorough deoxidation of the ore before it will be needed in the bath. Experience shows that for the ore now in use—compact, non-specular, red hæmatite, from the Minnesota Mine, Lake Superior—one hour is sufficient to give the desired reduction. The pig iron for the bath is charged into the hearth of the melting furnace as usual and brought to a molten state, and into this liquid bath there is charged from time to time, as each previous charge is melted, the contents of one of the four reducing chambers. With this exception the open-hearth process proceeds in the ordinary manner.

The cost of steel by the ordinary open-hearth method is estimated at from 6 to 19 dollars in excess of that by the Adams method, according to the class of steel made. It is stated that in this process but very little of either the phosphorus or the sulphur in the materials charged into the furnace pass into the reduced metal. The following are some mechanical tests of the metal produced by this process :—

1. Carbon, 0·13 ; silicon, 0·055 ; manganese, 0·60 ; phosphorus, 0·117 ; sulphur, 0·093—gave 60,000 lbs. tensile strength, 36,000 lbs. elastic limit, 25 per cent. elongation in 8 inches, and 52 per cent. reduction of area. The test bars were taken from ⅜-inch plate.

2. Carbon, 0·16 ; manganese, 0·92 ; phosphorus, 0·085 ; sulphur, 0·075—gave 64,720 lbs. tensile strength, 36,610 lbs. elastic limit, 23¼ per cent. elongation in 8 inches, and 50·35 per cent. reduction of area. Fracture 45° and silky. Test bar, 0·406 by 1·460 inch.

3. Carbon, 0·21 ; manganese, 0·98 ; phosphorus, 0·114 ; sulphur, 0·08—gave 66,950 tensile strength, 42,570 elastic limit, and 20¾ per cent. elongation in 8 inches. Test bar, ⅜ inch. It was defective, and the reduction of area could not be ascertained.

Other tests showed similar results.

FURTHER TREATMENT OF IRON AND STEEL.

Treatment of Steel by the Hydraulic Press.—The hydraulic press has been successfully applied at the Abouchoff Steelworks in order to obtain steel ingots free from blowholes. At these works there is a 10,000-ton press, the steel-making plant comprising two open-hearth furnaces, two crucible furnaces with gas firing, and two with coke firing, and one reverberatory furnace. In order to obtain perfect homogeneity in the metal, prolonged application is necessary of pressures amounting to 2000 to 2500 atmospheres, according to the volume of the ingot. In addition to the elimination of the blowholes, it is found that the ductility of the metal is notably increased.*

Reheating Furnace with Automatic Charging.—Drawings are published by Bildt † of a reheating furnace with hydraulic charging arrangements, which has been introduced at several works. The metal under treatment is raised by a hydraulic lift to the level of the charging door, which then opens automatically, and the metal slides down two water-cooled tubes into the furnace.

Apparatus for Charging Heating Furnaces.—Mr. S. Foster ‡ has designed an apparatus for this purpose. Mounted to roll on the jib of a crane is a trolley, to which is swivelled the upper end of a rod of peculiar shape. The gripping mechanism consists of two bars with spikes adapted to hold the ingot. These bars are connected by a coupling box, through which the upper bar may be moved longitudinally. The description is accompanied by an illustration of the apparatus.

Gjers Soaking Pits.—According to Mr. W. F. Durfee § the tonnage of steel ingots treated in Gjers soaking pits has greatly increased in

* *Revue Universelle des Mines*, vol. xiii. p. 326.
† *Jernkontorets Annaler*, vol. xlv. pp. 338-350.
‡ *Iron Age*, vol. xlvi. p. 986.
§ *The Iron and Coal Trades Review*, vol. xli. p. 439.

the last three years. The total quantity treated in 1889 was 938,000 tons. The pits are more largely used in Germany than elsewhere. In Austria the process is making headway, but there is not much progress in France or Belgium.

Use of Ankerite Powder in Welding.—J. Zgrzebny * has experimented with the use of powdered ankerite † as a protecting agent to prevent burning when welding steel faces to tools, and in welding generally. The welds proved good and clean, and the results gave considerable satisfaction.

Forging Wheels.—The process devised by Mr. J. A. Facer ‡ for the forging of carriage wheels direct from the ingot is as follows :—

Ingots of open-hearth steel of such size as to make when finished a wheel of the required diameter are heated in the furnace, and then placed under a hammer in which is adjusted the first set of dies. After the ingot has been thoroughly hammered on the circular side, or what afterwards becomes the tread and flange of the finished wheel, it is upset and by hammering reduced to a thickness that is somewhat greater than the wheel will be when finished. Then the billet is dropped on a projection on the front face of the lower die, which is so shaped as to represent a portion of the tread and flange of a finished wheel. There is a corresponding projection on the upper die. The billet is now turned slowly, and the dies strike a new portion of the tread each time they come together. A steel peg is set up so as to permit the hammer to descend only to that point, and thus the required diameter of the wheel is maintained. After the tread and the flange have been perfectly formed there is a complete wheel without a hub and the sides, which are entirely flat.

The disc at this stage is passed to another hammer, on which are fixed the finishing dies, which are of the exact shape of the desired wheel when finished, except in the case of wheels of large diameter. After the disc is exactly centred in the lower die, which is done by automatic gauging tools, the hammer is set in motion and the hub is formed. The sides of the wheel are then reamed out, the tread driven up against the barrel of the die and made exactly round and true. The only thing yet remaining to be done to the wheel is to bore the

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 32.

† A crystallised variety of dolomite containing a large proportion of iron.

‡ *The Buffalo Courier*, through the *Iron Age*, vol. xlvi. p. 915.

centre for the axle. The exception in wheels of large diameter is only that the disc goes from the first hammer to a set of fullers in the second hammer that forms the hub and partially reams out the wheel. These go to the third set of dies and are there finished.

Production of Hollow Iron Spheres by Pressure.—A method which has recently been devised for this purpose consists in the use of a hemispherical mould and a similar die, a piece of sheet metal being first moulded, and then the sphere completed by removing it from the mould and reversing it, completing the moulding in the same mould. Frequent annealing is necessary.*

New Boring and Milling Tool.—A universal boring and milling tool is described at considerable length in the *Iron Age.*† The machine has accurate adjustments, and means by which any piece of work may be placed in position before the spindle. As a milling tool it is of large capacity, rigid and simple in construction, and of great power of cut and feed. The gear cutting is stated to be well spaced, and the feed to be very fast. It is provided with a new circular milling attachment, which, by itself, performs the work of four lathes on such operations as turning the periphery and sides of gear blanks and similar work.

Horizontal Boring Machine.—A horizontal boring and drilling machine, designed by the Newark Machine Tool Works of New Jersey, differs materially from other machines of this type, especially as regards the feed arrangements. These have been greatly simplified, and any rate of feed, from $\frac{1}{80}$ to $\frac{1}{4}$ inch, is instantly available by the movement of a lever. The description of the machine is accompanied by an illustration.‡

Boiler Shell Drill.—A machine which was primarily intended for drilling the rivet-holes in boiler-plate is illustrated in the *Iron Age.*§ The drilling heads are mounted on a cross-head consisting of two horizontal beams supported at both ends by uprights, counterweighted and furnished with a power-lifting arrangement. The drilling heads are movable horizontally by means of a pinion gearing into a rack on the lower beam. They have also a rapid vertical adjustment.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 77.
† Vol. xlvii. pp. 1071–1075, eight illustrations.
‡ *Iron Age*, vol. xlvii. p. 1119. § Vol. xlvi. p. 845.

Steel for Milling Cutters.—In a paper read before the Institution of Mechanical Engineers,* Mr. G. Addy discusses the milling or shaping of metals by revolving cutters, giving illustrations of a number of such tools, and also the following analyses of milling cutter blanks made from best quality crucible cast steel, and from self-hardening Ivanhoe steel:—

	From Crucible Steel.	From Ivanhoe Steel.
Carbon	1·200	1·670
Silicon	0·112	0·252
Phosphorus	0·018	0·051
Manganese	0·360	2·557
Sulphur	0·020	0·010
Tungsten	0·000	4·650
Iron, by difference	98·290	90·810
Totals	100·000	100·000

Gear Cutting Machine.—In a paper read before the American Society of Mechanical Engineers at their Richmond meeting, Mr. A. Swasey describes and illustrates a gear generating and cutting machine of his design, and also discusses the question of gear cutting generally. By the new machine, instead of making all gears so that they will run into a rack, the rack is transformed into a cutting tool, and by its aid the teeth of wheels of any diameter are cut at the same time.

Planing Machine.—A large planing machine, capable of planing up to 12 feet square and 5 feet high, is illustrated in *Industries.*† It has a side standard for planing objects that will not pass between the standards of the machine. The tables are driven by two independent screws, which can be worked together or separately. The total weight of the machine is 35 tons.

Armour-Plate Planing Machine.—An unusually heavy machine for planing armour-plate or other heavy work is illustrated in *The Engineer.*‡ It will take articles 10½ feet square by 25 feet long, and it weighs 115 tons. The machine has two ordinary tool boxes on the cross slide with self-acting horizontal, vertical, and angular feeds. One of these can be replaced by a special box for cross-planing the ends of

* *Proceedings*, 1890, pp. 147–156, ten plates. † Vol. ix. pp. 452–455.
‡ Vol. lxxi. pp. 124–125.

plates, the table meanwhile remaining stationary. The front upright carries a fourth tool box with a copying motion, and a supplementary slide of great length for dealing with uncommon forms. The driving and feeding motions are all taken from the same shaft.

Ingot-Stripping Device.—Mr. C. Hyde * describes, amongst some hydraulic mill appliances, the ingot-stripping device of Mr. H. Aiken. The machine is carried on a trolley running on overhead beams. The ingots are cast in moulds on trucks which are run below the machine, which is lowered so that swinging arms pass over the head of the mould. A central ram is driven downwards to close these arms, and to expel the ingot as the mould is lifted by the outer ram on which the arms are pivoted.

Apparatus for Handling Ingots.—Messrs. J. Kennedy † and S. Foster have designed an arrangement to be used in handling ingots in charging and removing them from furnaces, &c. Trolleys are arranged to move to and fro on the jib of a crane, and these carry two rods bearing the gripping mechanism, which consists of two horizontal bars whose ends at one side are bent to a right angle to form points. The opposite end of the upper bar is threaded, and on this threaded portion is fitted a nut operated by a hand-wheel, by turning which the spiked ends of the bars may be adjusted to or from each other. When the jib is raised the spikes will firmly grasp the bloom, which is lifted by the upward movement and removed from the furnace by the movement of the trolley and jib.

Steel Castings.—P. Mahler ‡ discusses the subject of casting open-hearth and other steel. In the open-hearth furnace it is necessary that the steel should be fluid and free from impurities. Manganese is preferably present, but silicon has, in general, detrimental effects. The acid is preferable to the basic furnace, as the latter tends to promote oxidation. A suitable metal for the purpose of casting contains:—

Mn.	Si.	S.	P.
1·20	0·60	0·08	0·09

and has a tensile strength of 25 to 38 tons per square inch, and an elongation of 12 to 25 per cent.

* Paper read before the Engineers Society of Western Pennsylvania, through *American Manufacturer*, vol. xlviii. No. 6, p. 115, one illustration.

† *Iron Age*, vol. xlvi. p. 937, two illustrations.

‡ *Le Génie Civil*, vol. xviii. pp. 187–190 and 207–209.

The shrinkage in the mould tends to set up internal strains, but they may be largely obviated by annealing. It is necessary that the sand should be very dry, and that sufficient gas-vents should be used. The author gives a description of the furnace and of several castings, with analyses of the latter. As a general rule, castings in steel are more expensive than when made of cast iron, but their strength and lightness are much greater. Castings under 220 lbs. are difficult to make from a Siemens-Martin furnace, as the metal does not easily run into small moulds. Neither is it very practicable to make small steel castings from cupolas, so they must be made either from crucibles or from small converters. French crucible steel generally contains :—

C.	Si.	Mn.
0·8–1·5	0·3–0·8	0·1–0·6

Examples are given of small crucible castings, and reference is made to the use of aluminium, which is added towards the end of the fusion.

The author then discusses the manufacture of small castings made from a small vessel, such as the Robert converter. The metal being very liquid can be cast into green sand moulds, care being taken to supply enough to allow for shrinkage. The cost of these castings is intermediate between open-hearth and crucible castings, and accordingly they may be used in small foundries as well as in large works, though large castings will probably always be made from the open-hearth furnace.

Casting Solid Ingots.—Mr. W. R. Hinsdale * has devised a method for casting solid ingots, which consists in the use of a mould of peculiar shape, so arranged as to chill the top of the casting, and then to turn the ingot upside down before solidifying.

Manufacture of Shafts.—In discussing combined crank, crank and intermediate shafts for marine engines and their liability to fracture, Mr. C. H. Haswell † considers that crank shafts forged in one piece are liable to imperfections in welding both from laminations in the structure and cavities in the mass. The difficulty of forging such a large mass and afterwards machining it costs more than making the shaft and crank in separate parts, whilst, on the other hand, their strength when forged from faggots is of so positive a character that duplicates

* *Iron Age*, vol. xlvii. p. 242, four illustrations.

† *Transactions of the Institution of Naval Architects*, 1891 (advance proof).

need not be supplied. A faggot of square rolled bars presents a cohesion of the metal in the direction of its length best adapted to resist torsional stress, whilst slabbing presents cavities both transversely and longitudinally after welding. The centre of the shaft should also be bored out to lighten it, and in order that flaws may be detected.

Iron and Steel considered as Building Materials.—Mr. T. C. Fidler,* in considering iron and steel as building materials, shows that the capacity of yielding to stress before breaking, places mild steel at the head of a list of the strength of these materials when classified as to the work done on them before fracture. First-class Yorkshire iron follows closely in the list. Ductility is valuable not only in enabling the material to resist, but also in permitting the metal to adapt itself to local stresses. In dealing with the strength of beams, the author notes the failure of theory in properly calculating the transverse breaking load from the tensile strength. The bending in columns is next considered, and it is shown that it is desirable to remove the metal from the centre. The æsthetic side of the question is also dealt with.

Boiler Steel.—Mr. T. Mudd,† in dealing with some details of marine engineering, considers the use of steel for boilers. If this metal is of such a character as to be fit for this purpose it should bear the same treatment as iron, and it is well known that good mild steel will bear more punishment than iron will. Confident in this belief, the author, in 1884, began to build steel boilers. Having first provided special plant, he has built over two hundred high-pressure boilers without hitch, difficulty, or failure of any kind. As to whether boiler steel can be satisfactorily welded or flanged, the author states that experience over the many hundreds of shell welds that have been made in two hundred steel boilers, shows that, with common care, an ordinarily good workman can make a sound weld by using a best Yorkshire iron glut, and not a single weld has shown leakage. Perhaps the very best test of all that could be applied under the circumstances is applied to each individual weld, viz., the weld being made before the plate is flanged, has to stand the subsequent flanging in the hydraulic press, and it seems certain that if it were a mere surface weld it would divide when the disturbance caused by the flanger came upon it.

* Paper read before the Society of Architects, Jan. 13, 1891.

† *Transactions of the Institution of Naval Architects* (advance proof).

The author is of opinion that if boiler steel cannot be flanged at right angles with a fairly large radius in the corner when red hot without injury, it is not fit to build boilers with at all; and since he has now had flanged about a thousand large thick shell plates without returning to the makers more than two plates which showed slight surface tearings on being flanged, he has no hesitation in saying that ordinarily good mild boiler steel will stand this flanging in a perfectly satisfactory manner. With regard to local heating, there is probably a great difference in effect on the plate between heating along the edge and heating locally towards the middle of the plate. In any case the author again appeals to the large experience he has now had of this method as the proof that no damage accrues to the plate. It does, however, seem to be a wise precaution to anneal the plate after the welding and flanging is completed, and before any riveting is done, and therefore these shell rings are lowered flange downwards into an annular furnace, heated to a red heat, and allowed to remain to cool down with the furnace.

Wire Ropes.—Mr. A. S. Biggart * describes a number of experiments originally started for the purpose of selecting wire ropes for the Forth Bridge. The principal causes which lead to the destruction of wire ropes are: the wearing away of the outer surface of the outside wires, the rubbing of the wires against one another, and fatigue of the steel brought about when the rope is worked over a pulley relatively too small. Haulage cables for tramways wear out from the first cause, so that they may be made stiffer and the outside wires stronger, as they do not have to make sharp bends. Where small pulleys and sharp bends in the rope have to be used the rope must be flexible, and the experiments are chiefly directed to this point. The rope was strained over pulleys and reciprocated, the number of bends supported being counted. Tension and torsion tests of the wire used were also made. The failure of the ropes in all cases was occasioned by the individual wires gradually giving way, one by one. In no case were the outside wires severely worn even when the pulleys were so large that a great number of bends had to be supported. The principal stress to be regarded is that due to the bending of the individual wires and not that due to the load. The cutting of the wires where they cross each other, due to their longitudinal motion, accounts for the short life of ropes on small pulleys. The great effect

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. ci. pp. 231-248.

of this factor is seen in the tests of Lang's lay of rope, which undergoes a much greater number of bends than the ordinary lay. Oiling, also, by reducing the friction due to the longitudinal motion in the rope, has a great effect in lengthening the life of the rope. The results obtained in the course of the experiments are fully tabulated.

Drawing Crucible Steel Wire.—Mr. G. P. Clapp * states that the best grades of English crucible steel withstand a tensile stress of 200,000 lbs. per square inch, while American drawn wire will stand 185,000 lbs., the latter wire being much inferior, although it may have been made from imported wire. This, the author points out, is due to the treatment of the rod and wire in its various stages, English makers having a secret method of tempering which is only partially known in the United States.

Crucible, as well as other grades of steel rods, can only be reduced to a certain extent before the torsional qualities are partially or wholly destroyed. The tensile strength is increased and the twisting properties are decreased in proportion in all cases. Annealing steel wire destroys the tensile strength, which can only be brought back again at the expense of the torsional qualities required, unless the wire is tempered by lead and oil, or by some other process. From careful investigation there is no doubt that crucible steel rods, suitable for tempering in lead, oil, water, or otherwise, can be brought to a point where the greatest possible requirements are attained. This can be done by running the wire through hot lead and an oil bath kept at a known temperature, and reeling it at a certain speed. A perfect knowledge of the sizes of wire to be treated to produce other sizes that will stand all tests required must be acquired.

There is no known process of drawing crucible steel wire by slow or quick running blocks, or by light or heavy drafts, that will produce wire from the rods as it comes from the rolls to stand the tensile and torsional tests required for cable-road wire. Every reduction in size, by drawing, increases the tensile strength and reduces the twisting qualities. When wire with less tensile strength and more torsional qualities than required is reduced to a certain size, the two desired elements will be brought together. To get the best possible results the rod must be drawn to a certain size, then treated by some means that will give it the desired consistency to draw down to the size required, and this can only be done by thoroughly understanding

* *Iron Age*, vol. xlvii. p. 2.

the process of treating at the proper size, and then drawing to a certain other size, then testing to ascertain if requirements are correct.

If No. 14 is wanted, the proper size of wire to start with must be known and treated, then drawn to size. If upon testing at No. 13 the wire is found to have the proper qualities, another reduction will not do, as this will reduce the necessary torsion; the only remedy is to take a size smaller wire to start with or to make it somewhat softer. If the wire is found at No. 14 with too little tensile strength and more resistance to torsion than necessary, then the wire will have to be reduced still further to bring it to the most favourable point. After cleaning with hydrochloric acid, the wire may be drawn perfectly even-ended by exposing it to the atmosphere and sprinkling a weak solution of acid and water over it from time to time, until a dark brown water coat is deposited upon the wire, care being taken not to have the solution too strong. Too much acid makes the wire brittle and reduces the tensile strength as well. Since it is very close in the grain, baking and washing will not wash out and evaporate the acid, as in the case of other grades of soft steel and iron. Wire that does not stand the required tests when taken direct from the blocks often comes up to the standard by being exposed to the air two or three weeks. Perfectly dry hard soap must be applied to the wire while drawing, otherwise the wire scrapes and ruins the die plate.

Pipe-Threading and Cutting-Off Machine.—A machine for this purpose is described and illustrated in the *Iron Age.** Power is applied to a shaft, a head and dies are caused to revolve, and the work is forced into engagement with the dies by means of a lever, and caused to remain there until the threading is completed, when it may be disengaged by turning a handwheel and removing the dies.

Shafting and Pipe-Straightening Machine.—The Brightman Machine Company of Cleveland, Ohio, has designed a machine for straightening shafting. Chilled rolls are attached to blocks fixed to a large centre-piece, which is mounted on trunnions and revolved around the shaft by means of gearing. The blocks carrying the rolls can be set at any desired angle, and the bar fed through the rolls automatically; the capacity of one such machine being from 20 to 30 tons in ten hours.†

* Vol. xlvi. p. 843.

† *Iron Age*, vol. xlvi. p. 528.

Universal Sheet-Metal Cutting-Machine.—Messrs. Greenlee Brothers of Chicago have designed a machine for cutting thin sheet-metal without the use of special tools, dies, or patterns. The machine is simple in construction. It has a heavy iron body, on the top of which slide two head-blocks, each carrying two circular cutters. The head-blocks may be readily moved and locked. The cutters on the large head-block are easily adjusted to any position on the shafts on which they travel, the diameter of the bottom they will cut being shown on a scale. The pattern-table is supported and slides on a frame, by which it is firmly held. This frame travels on two steel guides placed parallel with the body. The table swings on a pivot, and can be quickly set and locked in any position. The sweep is readily adjusted to any radius above 3 inches, while the clamp on the end of the sweep is pivoted to the main horizontal arm, so that it may readily be adjusted to any desired angle.*

Rolling Nickel Steel.—M. C. Walrand † describes the rolling of ferro-nickel with varying percentages of the latter element, as carried out at the Forges de Montataire. The idea underlying the experiments was that ferro-nickel might replace copper and white alloys, owing to its non-oxidisability. The alloy used contained :—

C.	P.	S.	Mn.	Ni.	Fe.
0·15–0·05	0·02–0·05	trace	0·50–0·04	25·0	74·0

Mechanical tests gave the following results :—

1. On 0·59 inch rounds, turned to 0·47 inch in diameter, a 7·87 inch test-piece, before annealing, tensile strength, 56 tons per square inch; elongation, 19 per cent.; after annealing, tensile strength, 51 tons per square inch; elongation, 29·5 per cent. Flats, 2·6 by 0·24 inches, tooled to 0·67 by 0·24 inches, before annealing, tensile strength, 51 tons per square inch; elongation, 40 per cent.; after annealing, tensile strength, 46 tons per square inch; elongation, 33 per cent.

2. 1·02 inch rounds, turned to 0·47 inch in diameter, without annealing, tensile strength, 55 tons per square inch; elongation, 43·5 per cent. Rounds, 0·47 inch in diameter tested without tooling, without annealing, tensile strength, 43 and 45 tons per square inch, and elongation, 37 and 40 per cent. respectively.

The ferro-nickel was considered as a result of these experiments to be suitable for some special work.

* *Iron Age*, vol. xlvi. pp. 743–744, two illustrations.
† *L'Ancre de Saint Dizier.*

Tin-plate Manufacture in the United States.—The manufacture of tin-plates is a new industry in the United States. They are now being manufactured at Demmler Station, Pennsylvania. The plant has been in operation since January 1891, and the present output, which will shortly be largely increased, is from forty to fifty boxes a day. It is also proposed to lay down mills for the manufacture of the black plate.*

The first tin-plate manufactory in the United States has been erected at Chicago, some of the operatives having been previously engaged in Welsh tin-plate works.†

Rail Sections.—The committee of the American Society of Civil Engineers ‡ on standard rail sections, in an interim report, submits ten different sets of designs, prepared independently by members of the committee, for rails weighing from 40 to 110 lbs. per yard. The sections show a fair degree of agreement, considering that they were designed prior to all attempt at comparison of views. The following dimensions represent the figures obtained by taking an average of those proposed by the several members. For all sizes: top radius, 12 inches; corner radius, $\frac{1}{4}$ inch; sides, vertical; lower corner radius, $\frac{1}{16}$ inch; head, broad relatively to depth; base, equal in width to total height; distribution of metal, 42·5, 20·9, and 36·6 per cent. in the head, web, and foot respectively; angle of head and base, 13°; fillet radius, $\frac{1}{4}$ inch; radius of sides of web, 9 to 30 inches; extremities of base vertical, rounded off top and bottom. For different sections:—

Weight, lbs. per yard	40	50	60	70	80	90	100
Total height, inches	3·58	3·98	4·28	4·66	4·98	5·37	5·47
Width of head, inches	1·94	2·16	2·29	2·43	2·54	2·67	2·73
Depth of head, inch	1·02	1·12	1·27	1·39	1·51	1·60	1·70

An addition to the discussion on the use of hard or soft steel for rails is made by A. Stévart.§ To measure the wear of the rails either the decrease in height or the decrease in area must be determined, and these factors tell in favour of hard rails and of soft rails respectively. No attention appears to have been given to the relative wear of the wheel treads and the rails. The former undergo more use and are

* *Iron Age*, vol. xlvii. p. 475. † *Ibid.*, vol. xlvii. p. 1077.
‡ *Transactions*, vol. xxiv. pp. 1-12, one plate.
§ *Revue Universelle des Mines et de la Métallurgie*, vol. xiii. pp. 25-46.

more expensive, so that on their account the metal of the rails should be softer. The author then quotes from Sandberg, Dudley, and Osmond with regard to the chemical properties of the metal and the profile of the rail section, and concludes that there is not sufficient experience to settle the question, but that probably the steel should be of medium temper.

Wire-Wound Guns.—Owing to mechanical difficulties connected with the wire jacket, it has hitherto been found impossible to produce a satisfactory wire-wound gun. At present,* however, three guns of this kind are in course of construction in American arsenals. Each consists of a tube formed of a steel core built up in segments, around which is wound steel wire, and this in turn is protected by a steel jacket. The wire is wound under a uniform tension of 768 lbs. A test cylinder, which is an exact reproduction of the powder chamber of the 5-inch gun, is to be subjected to prolonged testing, using internal powder pressure far in excess of that of the heaviest service charge—about 25 or 30 tons per square inch, as compared with 13 to 17 tons. The steel of which the segments are made is a high grade Carpenter steel. In its annealed condition this steel gave the following results on being submitted to mechanical tests: elastic limit, 72,000 lbs. per square inch; ultimate tensile strength, 112,050 lbs. per square inch; elongation, 31 per cent. on 2 inches. After a special treatment by rolls the metal showed on testing: elastic limit, 126,000 lbs. per square inch; tensile strength, 175,000 lbs. per square inch; and elongation, 12 per cent. on 2 inches.

Flanging Machine.—A machine for flanging boiler heads is illustrated in *Iron.*† It is of the rotary type, and can be used with or without formers. If used without formers, inside rollers are employed. The plate is mounted on a vertical table, which is revolved by bevel gearing under the bearers, and the flanging rolls are gradually tilted by hand-worked worm gearing till the desired flange is attained.

Machine Tools at the Fairfield Shipbuilding Yard.—A series of articles given by *Engineering* ‡ contains descriptions and illustrations of some of the machine tools in the Fairfield shipbuilding yard. Among the recent additions to these works are a set of flattening rolls

* *Iron Age*, vol. xlvii. pp. 276-277. † Vol. xxxvi. pp. 293-296.
‡ Vol. l. pp. 246, 327, 443, 689.

capable of dealing with plates up to 8 feet broad and 1½ inch thick. Five rolls instead of seven are used in this machine. There is also a set of plate-bending rolls of unique design. The machine is entirely of steel, the end frames and gearing being cast while the rolls are forged. In order to make the machine efficient the rolls should be of small diameter, and this is attained by supporting the lower rolls by three sets of under rollers, while the upper roll is kept down to its work by a wrought steel girder, having on its under side three pairs of rollers, which act on the upper quarters of the main roll. With this construction the upper roll does not spring under heavy strains. There are four large lever double-punching and shearing machines with a 42-inch gap, and capable of punching 1½-inch holes through 1½-inch plates. A large keel-plate bender is also illustrated.

Circular Saws.—The first circular saws devised for cutting iron and steel in the cold were exhibited at Paris in 1878 by Messrs. Deneffe of Liége, and Western of London. These saws are compared, as to their arrangement and working results, with similar appliances exhibited at the Paris Exhibition of 1889.*

Cold Saw Cutting-Off Machines.—The Newton Machine Tool Works of Philadelphia have designed a number of different varieties of machines of this type, and they are illustrated in the *Iron Age*.† One of these saws is designed to cut armour-plate up to 10 inches in thickness, and up to 137 inches in length.

Oscillating Hot Saw.—Illustrations are given ‡ of a hot saw for ingots up to 10 inches square. The saws are 5 feet in diameter, and are driven by two cylinders 10 inches by 16 inches stroke, running at 250 revolutions, and driving the saws at 1500 revolutions per minute. The centre of the saw has a traverse of 20 inches, which is given by a horizontal steam cylinder 9 inches in diameter.

Armour-Plates.—Mr. C. W. Smith,§ at the Royal United Service Institution, stated that there were two principles that might be considered in making armour-plates—first, that of pure resistance depending on the identity of composition throughout the plate; and second, that

* *L'Industrie*, vol. iv. p. 523.

† Vol. xlvi. pp. 1122–1123, seven illustrations.

‡ *The Engineer*, vol. lxxi. p. 7.

§ *The Iron and Coal Trades Review*, vol. xlii. p. 93.

of hardness of face to resist the first impact whilst the broken face is held together by the softer material in the rear. Absolutely impervious armour is an impossibility, so that the only thing is to reduce the unavoidable damage to a minimum. A steel armour-plate graduated in its composition will best effect this, and the author points out the various methods of steel manufacture for attaining this end. The Darby re-carburising process is mentioned, and the use of three Siemens furnaces placed together, and making three different qualities of steel. The mould is divided by clean rolled steel plates, and the metal is run into the compartments of the ingot from the three furnaces simultaneously. There would thus be formed in one operation a quintuply graded ingot.

Gruson Armour-Plates.—In 1855 Gruson erected in Magdeburg a small machine works in which hard castings were a speciality. It having been found that these castings were suitable for projectiles, armour-plates were made of the same material. The armour-plates and projectiles now made by this firm are described at considerable length by Stercken.*

Armour-Plate Trials.—A test was made in March this year at Portsmouth of a plate manufactured by Brown & Co.† Three Palliser chilled cast iron shot were fired at it with a striking velocity of 1566 foot-seconds. The projectiles were broken, but the plate was only superficially cracked.

A series of trials of armour-plates took place at Ochta, Russia, in November last. Five shots were fired at each plate with a muzzle velocity of 2000 and 2100 feet per second. There were three plates submitted by Brown & Co., Schneider, and Vickers.‡ The first of these, a compound plate, resisted the first two shots, but the others penetrated. The Schneider all steel plate suffered severely. The Vickers plate, of softer steel, was not entirely penetrated, and did not show extensive cracks. Illustrations are given in the *Engineer* § of these three plates.

In a paper read before the Institution of Naval Architects,|| Mr. J. Barba gave a historical account of the various trials of the Schneider armour-plates.

* *Sitzungsberichte des Vereines zur Beförderung des Gewerbefleisses*, January 5, 1891.
† *Iron and Steel Trades Journal*, vol. xlviii. p. 333.
‡ *The Times*, through *Iron*, vol. xxxvi. p. 420.
§ Vol. lxxi. pp. 29-30
|| 18th March 1891.

A full description of the results of the recent American trials of armour-plates is given in *Le Génie Civil.** It is accompanied by several woodcuts and by seven plates, which fully show the condition of the armour after the several shots, and also the manner in which the shots were broken up. The matter is very fully entered into.

An illustrated account of the various recent armour trials is given by Captain Orde Browne in the *Naval Annual* † for 1891.

The Harvey Armour-Plate.—Details are published by Mr. B. G. Clarke ‡ of some trials of the Harvey steel armour-plate. Treated by a special process, the face of the plate is extremely hard, and the tests referred to gave such good results that it is stated that the armour-plate to be used for the new United States navy is to be submitted to this process.

Armour Trials at Low Temperatures.—A trial was made at Annapolis to determine whether the resistance of a nickel steel plate was affected by reducing its temperature below freezing point. A projectile was fired at the plate before freezing, and a second after the temperature was 28° F. The second shot was broken up badly, but it was not certain whether this was due to increased hardness in the plate or to the quality of the shot. The performance of the second shot was similar to that of the first, and did not appear to show that the plate was altered by reducing its temperature. Further trials will be made to determine this point.§

* Vol. xviii. pp. 177–183.

† Pp. 283–289.

‡ *Iron Age*, vol. xlvii. pp. 523–525, with illustrations.

§ *Iron*, vol. xxxvi. p. 518; *Iron Age*, vol. xlvi. p. 939.

PHYSICAL PROPERTIES.

Hardening of Steel.—In the United States, Redeman and Tilford * employ the method of hardening steel suggested by Captain Flodosieff,† in which glycerine and ammonia are used. It is claimed that soft steel may be converted into a hard variety, and that to Bessemer steel of poor quality the character of the best crucible steel may be imparted. Plates may be made soft on one side and glass-hard on the other.

The Flow of Metals and its Relation to Testing.—Mr. P. Kreuzpointner ‡ observes that, as is well known, in testing a bar of steel the maximum contraction takes place after the metal has attained its ultimate or maximum strength; that is to say, that the greatest percentage of contraction takes place during the period of a decreasing load which lies between the points of ultimate strength and final fracture. The rate of contraction before the ultimate strength is reached is very small, usually not more than one-fifth of the total reduction of area. This rate depends chiefly on the uniformity of structure of the material, and does not seem to follow any definite law, as is the case with the ultimate strength and the elongation. Local defects and irregularities in a metal influence the contraction to a far greater extent than they do either the tensile strength or the elongation, hence these two qualities seem to be far more trustworthy exponents of the value of the metal than is the contraction. The factors which determine elongation appear to be of a kind which tend to equalise the structure, whilst they at the same time are unfavourable to a uniform contraction. The author discusses the molecular flow which accompanies both the elongation and the contraction, and gives instances in proof of his assertions, and he concludes by referring to the statement of the President of the Iron and Steel Institute in 1879, that "the best manner of selecting iron and steel for a given purpose is by natural selection."

* *Berg- und Hüttenmännische Zeitung*, vol. l. p. 121.

† *Journal of the Iron and Steel Institute*, 1890, No. i. p. 328.

‡ *Iron Age*, vol. xlvi. pp. 700–701.

Effect of Tempering on the Electrical Resistance of Steel.—H. Le Chatelier * thinks that it is possible to arrive at the same conclusions as those of Osmond on the constitution of steel by measuring its electrical resistance, and the changes it undergoes under different conditions of hardening. He has made some experiments to determine this change. The increase in resistance due to hardening is only produced at a certain well-defined temperature, and does not increase with the temperature. The following table gives the resistance, in ohms, of one metre of wire, one millimetre in diameter, before and after hardening from the temperatures stated :—

Resistance	0·19	0·25	0·27	0·22
Carbon	0·085	0·48	0·67	0·83
Temperature	750°	745°	725°	735°
Resistance	1·13	1·18	1·55	1·60

This tends to show that the ordinary molecular state is stable below a temperature of about 730° C. On hardening steel the resistance decreases according as the temperature was raised and maintained. Practically the greatest change at any temperature takes place in a short time. The following shows for the third steel above mentioned the result of hardening at the temperatures given :—

Temperature	10°	128°	205°	310°	385°	450°	550°
Resistance	1·55	1·47	1·29	1·15	1·10	1·07	1·04

Similar results are obtained by hardening in a hot bath, as when the temperature of the bath is increased the resistance diminishes.

Electro-Chemical Effects of Magnetising Iron.—Mr. T. Andrews † gives the results of some experiments carried out by him on the effect of magnetisation on the relative electro-chemical position of a pair of bright iron bars, one magnetised by a coil, the other unmagnetised, when simultaneously exposed to the action of various powerful oxidising and saline solutions. Long polished rods of soft scrap iron were cut from the same bar, so that they might be as nearly as possible identical, and were placed in the legs of a U tube containing the electrolyte. The solutions employed were potassium chlorate with nitric acid or hydrochloric acid, also nitric, hydrochloric, and concentrated sulphuric acids. The magneto-chemical effects were very small. The magnetised rod was the positive element in every instance, except when dilute hydrochloric acid and concentrated sulphuric acid were

* *Comptes Rendus de l'Académie des Sciences*, vol. cxii. pp. 40, 43.
† Paper read before the Royal Society, *The Electrician*, vol. xxvi. p. 719.

employed. In the exceptional instances alluded to the electro-negative effect occurs, possibly owing to the presence of nascent hydrogen.

Heat Transmission through Cast Iron Plates.—In a paper read before the Richmond meeting of the American Society of Mechanical Engineers, Mr. R. C. Carpenter describes some experiments which were made with a view to ascertain the relative heat transmission through cast iron plates in the condition in which they left the foundry and after prolonged treatment with very dilute nitric acid. The tests showed that a loss of conducting power ensued, and that when using a nitric acid solution of a strength of 1 per cent. the loss varied directly with the time of immersion up to eighteen days, but that after this it remained constant. A 5 per cent. solution of the acid gave a greater loss of conductivity after a brief immersion of the plates, but at the end of forty days the result was the same with either solution.

The Mechanical Testing of Iron.—Professor L. Tetmajer * has published the results of further tests of iron and steel. Comparative tests made between weld iron and ingot iron resulted generally in favour of the latter, and even the weldability of the ingot iron seemed equal to that of the weld iron.

Punching tests showed that the tensile strength of the metal, whether weld iron or ingot metal, was higher between the holes than the original tenacity of the test-piece if the hole had been produced by boring, and lower if produced by punching. In the case of weld iron the change in the tenacity, however, is much less marked in both instances; that is to say, weld iron showed itself in these respects as well as in cold bending less affected by rough working than is ingot metal. The diminution in the strength of the weld iron produced by punching diminished with the increasing thinness of the metal under treatment, and it was also found that for a constant thickness of metal and a constant diameter of hole the loss of strength by punching is the greater the greater the distance is between the punched holes.

In the bending tests it was also found that the metal frequently broke in directions which did not accord with that in which it possessed the greatest bending moment.

Reduction of Area as a Measure of Quality.—Mr. P. Kreuzpointner † discusses the value of the reduction of area observed in a

* *Stahl und Eisen*, vol. xi. pp. 148–149.
† *Iron Age*, vol. xlvi. pp. 1075–1076; vol. xlvii. p. 151.

test-piece after its submission to tensile test as a measure of the quality of the material examined. Examining the subject from a theoretical point of view, he shows that contraction begins after the metal has exhausted its strength, and after it has completely changed its nature. Not so the elongation up to this point; and while this is a measure of the quality, the author considers that such is not the case as far as the reduction of area is concerned.

Tests of Basic Steel.—Mr. J. Davis * gives the following results of some mechanical tests of basic open-hearth steel made at the Park Gate Steelworks:—

Analyses.		Dimensions of Test-piece.			Breaking Strain.		Elongation on 8 Inches.
		Width.	Thickness.	Area.	On Piece.	Square Inch.	
		Inches.	Inches.	Inches.	Tons.	Tons.	Per Cent.
C . . .	0·15	0·98	0·98	0·96	28·1	29·27	22·0
Si . . .	trace	0·98	0·89	0·87	25·0	28·73	24·0
S . . .	0·43	0·98	0·74	0·72	20·2	28·0	28·0
P . . .	0·06	1·47	0·68	0·99	29·2	29·5	24·0
Mn . .	0·60	...	...	...	...	...	...
C . . .	0·14	1·47	0·38	0·55	16·0	29·0	25·5
Si . . .	trace	1·46	0·49	0·71	19·9	28·0	25·0
S . . .	0·046	1·50	0·63	0·94	27·1	28·8	21·0
P . . .	0·052	1·49	0·80	1·19	34·5	28·9	22·5
Mn . .	0·61	1·49	0·79	1·17	34·6	29·5	22·0
C . . .	0·12	1·27	0·48	0·60	16·6	27·6	23·0
Si . . .	trace	1·47	0·43	0·63	17·1	27·0	22·5
S . . .	0·050	1·45	0·49	0·71	19·6	27·6	25·0
P . . .	0·05	1·47	0·45	0·66	17·9	27·1	24·0
Mn . .	0·58	1·48	0·37	0·54	14·6	27·0	23·0
		1·49	0·34	0·50	13·7	27·4	22·5
C . . .	0·10	2·38	0·15	0·357	7·8	22·1	29·5
Si . . .	trace	2·40	0·16	0·384	8·3	21·6	29·5
S . . .	0·035	2·39	0·21	0·501	11·3	22·5	30·0
P . . .	0·045	2·40	0·17	0·408	9·1	22·3	32·0
Mn . .	0·56	1·51	0·34	0·52	12·9	24·8	28·0
		1·55	0·38	0·58	14·6	25·1	25·0

Basic Bessemer Metal.—Professor L. Tetmajer † discusses the value of basic Bessemer iron for construction purposes. With a view to elucidate this question the author has made about 1500 separate experiments, the material for which, about 31½ tons in weight, was

* Paper read before the Cleveland Institution of Engineers.
† *Schweizerische Bauzeitung*, 1890, Nos. 18 and 19.

derived from a number of German steelworks. The investigation was originally started by R. Erhardt, and consisted of a comparative examination of basic iron for I-beams. Experiments made in Austria, on what was stated to be a somewhat large scale, led to basic Bessemer metal being condemned as far as construction purposes were concerned, and this necessitated the elaborate character of the author's investigation.

His first experiments relate to the resistance of the metal to pressure, and he prefaces his remarks by a consideration of the methods which have hitherto been adopted for such determinations. Formerly it was deemed that the point to be determined was that at which a marked broadening of the test-piece could be observed, but neither this nor Professor Bauschinger's system of short cylinders gives satisfactory results. Experiments show that there are in such pressure tests three main points of the resistance, the elastic limit, the yield point, and the limit of cohesion, this latter point in the pressure tests being that at which the metal assumes a plastic condition of deformation, similar to the flow of the metal during the reduction of area preceding the fracture in a tensile test. It is this point which should be determined.

From the results of these experiments and a prolonged investigation of the other properties of the metal, the author concludes that basic Bessemer iron is fully as good as weld iron for the purposes of construction.

The author discredits the results of the Austrian experiments to which reference has already been made. As compared with the open-hearth process, the basic Bessemer process undoubtedly stands at a considerable disadvantage, the open-hearth metal being decidedly the better of the two, the length of time it is under treatment being so highly favourable to the production of a metal of high homogeneity. When it is a question of the production by the basic Bessemer process of metal which is to be used in the construction of bridges, exceptional care should be taken in obtaining the samples for test purposes, and each charge should be carefully followed. This, however, need lead to no difficulty.

Tests of Bridge Steel.—A number of tests of steel used in the Clarence bridge at Cardiff are given in *Engineering.** The specifications of the tensile strengths of steel and wrought iron in plates, angles,

* Vol. li. p. 350.

and bars are given, and also the tests of the materials furnished. Amongst others are given the tests of some full-sized eye bars and a half-sized steel link.

Tests of Mild Steel.—As steel frames, pressed from large sheets of mild steel, are being used in the construction of pianofortes, it became necessary to make some tests of the material in order to determine approximately the best section at various parts of the frame which has to support a pull of some 16 to 18 tons due to the wiring. For this purpose a test-piece 18 inches long, 3·261 inches wide, and 0·401 inch thick, was bevelled off at the ends, and submitted to a compressive stress which bore on the salient angles only. The deflection was as follows on the central twelve inches :—

Load in tons . .	0·6	1·1	2·1	3·1	3·6
Deflection, inch. . .	0·005	0·016	0·037	0·079	0·172

Permanent set of 0·19 inch was given by a load of 3·9 tons. Under tensile stress this steel showed an elastic limit at 16·3 tons per square inch, maximum load 27·8 tons, and elongation on 8 inches 30 per cent.*

Experiments with Boiler Steel.—The results of a series of experiments with boiler plate material, made at the Royal Testing Institute, Berlin, are given and discussed by Rudeloff.† Both mechanical and chemical tests are given, but the latter are not so uniform as the former. The results of annealing and hardening in the tests, both with and across the grain, are given. Annealing has but little effect, but there is considerable difference due to hardening, especially in the case of open-hearth steel. The fractures in these and other experiments are illustrated by photographs. Punching tests showed that basic iron is tougher than wrought iron. All tests showed the injurious effect of working at a blue heat and hardening. Hot and cold bending tests were performed, and show that basic steel bends less than the open-hearth steel. The general conclusions of the author are that annealing does not produce much effect on open-hearth steel unless the carbon is high, while the toughness is greatest with high carbon and low phosphorus. Basic steel of approximately the same composition as open-hearth steel has generally a greater breaking strength and a lower extension both when annealed and unannealed. The effect of hardening, according to tension tests, is least noticeable in basic steel, and, accord-

* *The Engineer*, vol. lxxi. p. 56.

† *Mittheilungen aus den Königlichen Technischen Versuchsanstalten zu Berlin*, 1890, p. 289, with two plates.

ing to punching tests, is more marked in basic steel than in open-hearth steel. Blue heat is generally prejudicial. Finally, it would appear that basic steel is suitable for boiler construction.

Tests of Gun-Barrels.—A committee of the Guardians of the Birmingham Proof-house have recently issued a report on a series of tests of various kinds of English and foreign gun-barrels employed in sporting guns. The barrels were of various makes, some being twisted and hand or machine forged. In all, thirty-nine specimens, numbering 117 barrels, were tried. All barrels were made true to one gauge, and were tested with increasing charges of powder and shot till they were bulged too much to be passed by the proof master. The relative results of the various tests are given, and the specimens are arranged in order of endurance. The series of experiments presents the comparative elastic limit of the different kinds of material, and the influence of the manufacture of the tubes. The endurance appears to depend upon a moderately high elastic limit, which prevents bulging, and upon a fair margin between the elastic limit and the breaking strain, which prevents bursting. The most suitable condition appears to be attained by judicious rolling or working at a moderate heat, with as little reheating as practicable. The elasticity and tenacity are affected by the purity of the metal, and by the mode of twisting and laying the rods together. Overtwisting may reduce the tenacity, and the temperature at which the metal is worked may, in some cases, account for discrepancies in the behaviour of the barrels.*

Strength of Railway Couplings.—An account is given by A. Pulin † of experiments made on the Northern Railway of France to determine the drawing strength of railway couplings. Impact tests with a falling weight of 1180 lbs. were employed, either with increasing or with a uniform height of fall. Results of the trials are given.

Stay-bolt Iron.—The following are the results of mechanical tests of two samples of Tennessee bloom stay-bolt iron: ‡—

Area, square inch	0·6793	0·9852
Broke at, lbs.	35,725	50,950
Breaking strength, lbs. per square inch	51,100	1,720
Limit of elasticity, lbs. per square inch	35,700	2,000
Elongation of reduced section	1·44	1·31
Per cent. of elongation	36·0	32·8
Area of reduced section	0·3068	0·4902
Per cent. of reduction	55	50

* *Iron and Coal Trades Review*, vol. xlii. p. 295.
† *Revue Générale des Chemins de Fer*, 1890, p. 135.
‡ *Iron Age*, vol. xlvii. p. 146.

Tests of Hoop Iron.—The following* are the results of some tensile tests of American hoop iron used for petroleum barrels :—

	Elongation per Cent.		Tensile Strength, Lbs. per Square Inch.
1	13·5	...	56,600
2	15·6	...	58,700

Torsional Testing Machine.—A machine of this type, manufactured by Messrs. Riehlé Bros. of Philadelphia for the Union Pacific Railway Company, is illustrated in the *Iron Age.*† It is of the multiple lever type, and can be worked either by hand or by power.

A 1200-ton Testing Machine.—An hydraulic 1200-ton testing machine has been erected at the works of the Phœnix Iron Company, Pennsylvania. The total length of the machine is 78 feet, and it will take an eye-bar 50 feet in length. It is a modification of the Kellogg machine, and is described and illustrated in the *Iron Age.*‡

A New Testing Machine at Przibram.—A. Gstöttner § describes a testing machine which has been erected at Przibram. It is intended more especially for the testing of wire rope, and can exert a tensile stress of 80 tons. It is a hydraulic machine of the Pfaff type. The description is illustrated by two plates of drawings.

Testing Machine.—Illustrations are given || of an 80-ton testing machine which is primarily intended for testing wire ropes. It is of the vertical hydraulic type. The press cylinder is below the floor, and the piston carries a vertical screw to which the gripping device is connected. The main beam is horizontal, and is supported on knife edges in cast iron uprights, which form the frame of the machine. The lever ratio is 1 to 500, and the load is applied at the end of the lever and by a travelling weight, which can be moved by a screw and mechanism which is automatically controlled so as to start or stop according as the lever is level or not.

* *Iron Age*, vol. xlvii. p. 200. † Vol. xlvii. p. 1076.

‡ Vol. xlvii. pp. 142–145, eleven illustrations.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 478.

|| *Revue Générale des Machines Outils*, November 1890, through the *American Manufacturer*, vol. xlviii. No 9, p. 183.

CHEMICAL PROPERTIES.

Carburisation of Iron by the Diamond.—F. Osmond * has experimented on the carburisation of iron by the diamond with a view to determine the temperature at which this takes place. He used electrolytrically deposited iron and fragments of diamond known as *uitschot*. The diamonds were placed on the iron and heated in an atmosphere of hydrogen. The first experiment was made between 1035° C. and 1055° C., below the melting point of white iron. The absorption of carbon at that temperature was observable, but was very slow. At temperature between 1085° C. and 1125° C., above the melting point of white iron, a button of white iron was obtained. When more diamond than is necessary for complete saturation is used, the excess is converted into graphite. It follows from these experiments that the diamond itself does not carburise the iron, but undergoes, in contact with the metal, a molecular alteration which enables it to combine with the iron. At the same time there is a diffusion of iron into the transformed diamond.

Loss of Carbon in Rusted Pig Iron.—Mr. J. G. Donald † has determined the loss of carbon due to the rusting of pig iron with the following results:—

	No. I.	No. II.
Rusted drillings . . .	1·941 per cent.	1·332 per cent.
Original sample . . .	2·282 ,, ,,	2·132 ,, ,,

The combined carbon in the first sample was 0·378 per cent., in the second 0·336 per cent., so that rusting has caused a partial disappearance of the graphite.

The Passive State of Iron and Steel.—Mr. T. Andrews ‡ has continued his researches on the passive state of iron and steel. His

* *Comptes Rendus de l'Académie des Sciences*, vol. cxii. pp. 578–580.
† *Chemical News*, vol. lxiii. p. 73.
‡ Paper read before the Royal Society, January 22, 1891. *Nature*, vol. xliii. p. 358.

third series deals with the effect of temperature on the passivity. Unmagnetised polished rods cut from the same bar were used and placed in a U tube, one limb of which could be warmed and the other cooled. The electro-chemical results obtained show that wrought iron is less passive than steel in warm nitric acid, and the behaviour of the steel is less uniform. The passivity is not fully lost till a temperature of 175° F. is attained, although it is considerably modified.

The third series deals with the relation of passivity to the concentration of the acid, and shows that they increase together. Wrought iron is less passive in weaker acids than most steels.

The Corrosion of Iron.—The various ways in which iron may be corroded are described by Mr. R. Irvine.* The comparative liability to oxidation according to Mallet is, cast iron 100, wrought iron 129, and steel 133. Gmelin states that the purest iron rusts most quickly; sulphur accelerates and phosphorus retards the action. It is when exposed to damp air containing carbonic anhydride that rusting takes place, due to galvanic action, according to Calvert. A second form of corrosion is due to the presence of sulphuric and carbonic acid in the air of cities. Sea-water has a powerful solvent effect on wrought iron, and sulphide of iron is produced when decaying organic matter is present. An example of this is given in a mooring chain covered with animal life, where the skin of sulphide was an eighth of an inch thick. Galvanic action between two forms of the same metal is also a common cause of corrosion. This is seen in boilers or in propellers where part is cast iron and another part wrought iron or steel. Iron rails and sleepers also form an example, and a case is cited where the rail was much eaten away inside a tunnel. Under all circumstances there is a strong galvanic action between the two metals, and much may be ascribed to its ill effects. Metallic pigments are likely to have a similar effect, and the author recommends the use of boiled linseed oil as a preservative covering.

Corrosion of Steel and Iron by Salt Water.—Mr. D. Phillips † states that he has experimented with two plates of Bessemer boiler steel, two of Yorkshire iron, and two of BB Staffordshire boiler iron. The plates were 6 by 6 by $\frac{3}{8}$ inches, and were kept immersed in salt water from 1881 to 1888. The results showed great differences in the

* *The Journal of the Society of Chemical Industry*, vol. x. pp. 237, 238.

† Paper read before the Institute of Marine Engineers, May 13, 1890.

behaviour of the steel and the irons. The steel lost 120 per cent. more than the irons during the first three years when the plates were in contact; 124 per cent. more in the second three years when they were insulated; and 126 per cent. more for the whole period of seven years.

Effect of Pickling and Rusting on the Strength of Iron.—A. Ledebur * describes experiments carried out in order to obtain information with regard to the brittleness imparted to iron by the action of acids in pickling and by rusting. Previous experiments have been made with wire, and the present series has been made with larger objects, such as rails and bars. The objects were tested as they were delivered, after exposure for rusting; galvanised and tested both immediately and after exposure; pickled and tested immediately or after some time. Tensile and crushing tests, and tests under a falling weight were made. The tabulated results are set forth at great length, and the general conclusions given indicate the effects produced. In bending tests with wrought iron joists, the elastic properties and deflection are practically not affected by the treatment, but the breaking strain is reduced by recent pickling and to a smaller degree by rusting. None of the methods of treatment had any great effect on the bending tests of the steel rails, nor on the tensile tests with round steel or iron bars. The strength of both iron and steel wire is diminished by rusting or pickling. No sensible differences in the compression tests were observed, but pickled wrought iron was bent more by a falling weight than the untreated metal. The probability of brittleness arising from pickling or rusting is least in cast iron and steel containing silicon and greatest in wrought iron. Combined carbon appears to increase the action, whilst silicon has the reverse effect, and that of manganese has not been determined.

Action of Hydrochloric Acid on Pig Iron.—In some experiments to determine the action of hydrochloric acid on pig iron, Dr. Prost † employed a white pig iron containing:—

Iron.	Combined Carbon.	Graphite.	Phosphorus.	Silicon.
85·920	2·685	0·465	2·700	0·915

On this pig iron, in the state of powder, he allowed twice the weight

* *Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin*, 1890, Supplement I.

† *Revue Universelle des Mines*, vol. xi. p. 308.

of hydrochloric acid that was theoretically required for dissolving the same weight of pure iron to act in accordance with the equation :—

$$2Fe + 4HCl = 2FeCl_2 + 4H$$

The degree of concentration of the acid varied in different experiments. In each case the sample was allowed to stand for six hours at 85° C.

The appearance of the residue was very variable, the total residue (4·19 to 41·33 per cent.) was in direct ratio to the degree of dilution of the acid (311·00 to 29·32 grammes of hydrochloric acid per litre). Analysis of the residues showed that the composition varied. The percentage of carbon (2·35 to 12·54), of hydrogen (0·12 to 2·07), and of phosphorus (0·93 to 11·66) increases with the degree of concentration of the acid, whilst the percentage of iron (91·80 to 23·22) decreases.

When the amounts of the various constituents are referred to an equal weight of pig iron, say to 100 parts, some interesting results are obtained.

It is then seen that with increasing concentration of acid, that is, with increasing attacking energy on the pig iron, the residue contains :—

Iron . . .	37·947 to 0·972
Carbon . .	1·047 ,, 0·625
Hydrogen . .	0·050 ,, 0·087

With regard to phosphorus, the results are irregular; the largest quantities in the residue are obtained with acids of average concentration.

The Elimination of Sulphur from Iron.—A method has recently been patented by the Hoerde Steelworks which consists in adding manganiferous iron in considerable quantities to the sulphurous iron under treatment. The manganese is stated to combine with the sulphur, which can then be removed in the form of slag.*

Sulphur in Bessemer Steel.—In the manufacture of soft steel by the Bessemer process from certain kinds of pig iron, the metal has sometimes a tendency to boil violently in the moulds. Mr. J. W. Cabot † shows that this behaviour may be due to absence of sulphur in the metal. At Bellaire, Ohio, the direct metal from the blast furnace shows this tendency to rise, while the remelted metal which has taken

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 202.

† *Transactions of the American Institute of Mining Engineers*, vol. xix. (advance proof).

up sulphur from the coke gives quiet castings. The following analyses show the average composition of the rising steel and the quiet metal respectively :—

Carbon.	Manganese.	Silicon.	Sulphur.
0·090	0·36	0·009	0·030
0·084	0·39	0·009	0·058

It is well known that sulphur forces the carbon in the iron into the graphitic state. This renders it more liable to be burnt out during the blow before the iron is attacked. This is borne out by the character of the change in the flame, which is quick and decided. In order to test the theory, sulphur was added to increase the 0·01 or 0·02 per cent. up to 0·05 or 0·06 per cent., and in every case the steel poured quietly. The sulphur was added in several ways, by adding coal or shale to the heats or by mixing in a high sulphur pig. Mechanical means might overcome the boiling in low sulphur steel, but 0·04 to 0·05 per cent. of sulphur seems to have a favourable result on the reactions.

Aluminium in Steel.—Professor Arnold * has investigated the action of aluminium on steel. In some cases his results are in opposition to those obtained by Mr. Hadfield, as far as the removal of blowholes is concerned; but most of his experiments were made with crucible cast steel or very mild steel. The best form in which to apply the metal is not ferro-aluminium but as the pure metal itself. Though its use tends to remove blowholes, yet it causes the ingots to pipe. This tendency can, however, be obviated by coring. The water crack in crucible steel is probably due to manganese and silicon, and in aluminium is found a means for removing impurities. The use of aluminium eliminates blowholes, and permits the use of a much milder metal. Microscopic sections of the steel were used to illustrate the change of structure.

The effect of aluminium on castings is to reduce flaws. In discussing this paper, Mr. B. W. Winder stated that two kinds of blowholes were found in ingots, one of these was blueish-black and contained oxygen. Aluminium, he finds, entirely eliminates this kind by absorbing the oxygen, and prevents boiling up during teeming. Mr. Scott finds that the use of aluminium causes a saving in coke.

* Paper read before the Sheffield Technical School Metallurgical Society; *Iron and Steel Trades Journal*, vol. xlviii. pp. 309, 399; *Iron and Coal Trades Review*, vol. xlii. p. 265.

CHEMICAL ANALYSIS.

CONTENTS.

I.—*ANALYSIS OF IRON AND STEEL.*

Iron and Steel Analysis.—A criticism has appeared * of the description, by Mr. J. W. Langley, of the results of the investigations of the committee of United States analysts relating to standard analytical methods for iron and steel, which showed :—(1) That very accurate results may be obtained by determining the carbon by combustion in a current of pure oxygen in a porcelain tube, provided the manipulation be carefully performed. (2.) If the carbon is accompanied by chlorine it is necessary to place a silver spiral in the combustion tube, and to pass the products of the combustion through a solution of a silver salt, and more especially one of silver sulphate. (3.) That the carbon may be completely oxidised by chromo-sulphuric acid. If, in this case, the carbon is accompanied by chlorine, it would appear best to use a reducing agent, such as pyrogallic acid or potassium oxalate, and to use as an addition to the reduction tube another filled with a silver solution. Under these conditions the method gives perfectly accurate results. (4.) That the addition of a small quantity of hydrochloric acid to a solution of copper-ammonium chloride always gives a higher result than would be obtained were no hydrochloric acid employed and the solution a neutral one. (5.) That to replace the ammonium chloride by potassium chloride is without any advantage. (6.) The most important result of the investigation consists in the discovery of the unequal and irregular action of copper-ammonium chloride. It was found that the results of determinations made with this solvent on the same steel gave results which varied between 1·016 and 1·150. If the percentage of acid pre-

* *Stahl und Eisen*, vol. xi. pp. 49–54.

sent remains constant the percentage of carbon found will vary with the method of preparation, and with the number of recrystallisations to which the double-chloride had been submitted. (7.) That the carbon liberated by the copper-ammonium chloride appears not to diminish in weight when dried at a temperature below 100° C., but it does so if dried at a higher temperature.

In referring to Mr. Langley's paper the writer in *Stahl und Eisen* criticises the results somewhat severely. He observes that the members of the committee might have saved themselves much trouble had they been better acquainted with the literature of the subject. Thus Sarnström, in 1884, showed, in comparing the various methods for the determination of carbon in iron, that copper-ammonium chloride is liable to give low results; that since that date A. Brand has investigated the cause of this error, and has found that with alkaline or neutral solutions of copper-ammonium chloride there is an evolution of hydrocarbons, and that the resulting error is so great as to render the process absolutely useless. What is stated by Mr. Langley to be the most important discovery is therefore no discovery at all. The use of the pyrogallic acid solution is also open to objection, owing to the possibility of an evolution of carbonic anhydride.

Differences in Iron Analyses.—J. Kail * gives the results of a number of control determinations of carbon and silicon made from different portions of the same piece of white pig iron, the carbon being determined by the accurate method of Gmelin, and the silicon by the Drown method, as modified by Gmelin. How greatly the results varied the following table shows :—

Sample.	Carbon.	Silicon.
	Per Cent.	Per Cent.
1	2·87	0·19
2	2·77	0·19
3	3·82	0·12
4	3·01	0·14
5	3·41	0·40
6	3·41	0·41
7	3·77	0·16
8	3·43	0·12
9	3·79	0·20
10	3·78	0·23

The author concludes that it is a matter of extreme difficulty to obtain

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 506.

a sample which shall really represent the average composition of the metal.

The Determination of Carbon.—A. J. Rossi * describes various modifications of the ordinary Eggertz colorimetric method, as adopted at Seraing, Rothe Erde, and Liége. The first consists in the use of a series of colour standards as in copper determinations, while at the Société d'Angleur Works, Liége, the method is as follows:—

A Duboscq colorimeter is used, of which the construction is based on this principle: Two solutions of the same substance which, examined under a different thickness, have the same shade, contain quantities of the substance inversely proportional to their thicknesses. The apparatus is composed essentially of two glass cups of the same diameter and thickness. Into the interior of each of these cups can be lowered a small cylinder of unpolished glass. The vertical motion of these cylinders within the cups is regulated by means of a system of screw and rack; a vernier connected with the screw and moving on a straight millimetre scale allows reading to the millimetre the amount of motion imparted to the cylinder of each cup. A reflecting mirror inclined at 45° concentrates the rays of light towards the bottom of the cups. These rays penetrate into the interior of the small cylinders through the whole length of the latter, and are received on a double refraction prism provided with a small telescope. The disposition of the system is such that the optic field of the telescope receives the rays of light reflected by each cup in the interior of the cylinders, each pencil of rays occupying half of the field of vision. An horizontal wire stretched according to a diameter of the lens marks the limits of each pencil of light. To guard against any loss of light by diffusion, whenever the apparatus is used the two cups are protected by a kind of camera obscura in wood. The operation is conducted as follows:—

The characteristic point of the method is that only one solution of one normal steel is required, whatever may be the carbon contents of the specimen to be tested. 0·20 gramme of a normal steel containing say 0·34 per cent. carbon is dissolved in 10 cubic centimetres of nitric acid, specific gravity of 1·2, and an equal weight, 0·20 gramme of the specimen to be analysed is treated in exactly the same manner. The liquids are heated to 80° or 85° C., and, after three-quarters of an hour to one hour, the solution of the carbon is generally

* *Iron Age*, vol. xlvii. pp. 478–479.

complete. The tubes containing the solutions are cooled in water, and as a small amount of nitric acid might have been evaporated, one drop to two drops of the acid is added. One of the cups is then filled with the solution of the normal steel, and the corresponding glass cylinder is lowered down by means of the screw until the zero of the vernier coincides with the division corresponding to its carbon contents, as read on a scale graduated in advance according to a conventional table. The other cup is then filled with the solution to be tested, and looking through the glass of the telescope, the second cylinder is lowered in its turn until a complete equality of tint is obtained in the field of the glass; the corresponding division of the scale is then read. Let a and a' be the carbon contents of the normal and tested solution, b b' the respective heights read on the scale. $\frac{a}{a'} = \frac{b'}{b}$; $a' = \frac{ab}{b'}$; a discrepancy of $\frac{2}{1000}$ between two consecutive determinations, and 0·02 per cent. is the only margin admitted for the same sample.

When dealing with very soft steels, the normal type of steel is changed, because, as it is strongly coloured while the tint of the very soft steel is very light, it would become necessary, to obtain the equality of shade, to make the thicknesses of the liquid vary beyond the limits of motion of the apparatus. In such cases the normal steel adopted contains only 0·03 per cent. of carbon.

The Determination of Phosphorus.—Dr. M. A. von Reis * discusses the determination of phosphorus by the aid of the centrifugal separator. The preliminary experiments with this apparatus gave satisfactory results, but it was soon found, on applying the process practically, that the results were irregular, mainly owing to slight variations in the composition of the nitric acid and other liquids employed. It was early observed that the phosphorus precipitate is easily affected, and thus the slight variations just referred to were of considerable influence on the volume of the precipitate, and, consequently, on the calculated result. It was consequently found necessary to be continually testing the solution with the areometer, and to make comparative determinations by the ordinary methods of analysis in order to determine the influence of this factor. These check weighings are always advisable, as four or six of them can be done in about the same time as fifty or sixty by the centrifugal method. To avoid the varia-

* *Stahl und Eisen*, vol. x. pp. 1059-1060.

tions in the results, and thus to render the process more accurate, experiments which were made to this end led to its being found that by using double the quantity of the molybdenum solution, as compared with that usually employed, the results became more satisfactory. The use of a stronger acid, too, proved advisable, as also did a lower temperature for the precipitation.

The author now adopts the following method of procedure:—Take 3·5 grammes of the steel under examination, and dissolve the metal in 50 cubic centimetres of nitric acid of 1·23 specific gravity. Then oxidise with potassium oxalate and some permanganate, add 80 cubic centimetres of a solution of ammonium nitrate, containing 160 grammes of ammonium to the litre, heat to boiling, allow to cool to about 95° C., and then add 50 cubic centimetres of the molybdenum solution. By adding the precipitating agent to the solution when at this temperature, and allowing the whole to stand, when the temperature has fallen to about 75° the phosphorus precipitate will settle well and clearly. By this method of preparation it was somewhat curious to observe that the volume of the precipitate was not directly proportionate to the percentage of phosphorus, but that with increasing phosphorus the volume of the precipitate increases slightly but regularly, as the following table shows:—

Volume.	Percentage of Phosphorus.	Volume.	Percentage of Phosphorus.
2	0·007	60	0·140
4	0·014	70	0·156
6	0·020	80	0·167
8	0·020	90	0·180
10	0·032	100	0·200
20	0·060	102	0·204
30	0·084	104	0·208
40	0·104	106	0·212
50	0·120	110	0·220

Very accurate results can be obtained by the process as thus modified.

M. Mauermann * determines the phosphorus in iron or steel by precipitating with molybdate in the ordinary way, then dissolving the precipitate in very dilute ammonia, and titrating back the excess of ammonia by very dilute sulphuric acid. The process is stated to admit of much greater accuracy than the ordinary gravimetric method.

The Colorimetric Determination of Phosphorus.—Professor R. Namias † describes the colorimetric determination of phosphorus,

* *Stahl und Eisen*, vol. xi. pp. 288-289.
† *Ibid.*, vol. x. pp. 1060-1061.

based on the intense blue colour of a solution of the ordinary phospho-molybdate precipitate in a hot solution of sodium hyposulphite. If then such a coloured solution is compared with the solution obtained from iron containing a known percentage of phosphorus, it is evident that the percentage of phosphorus sought can be readily determined.

The method the author adopts is as follows:—The precipitation of the phosphorus is effected by the molybdate solution in the usual manner; the precipitate, however, is washed with a solution of ammonium chloride instead of the customary ammonium nitrate solution. This ammonium chloride solution is of 5 per cent. strength, and is used hot. The washed precipitate, when the wash water ceases to show an acid reaction, is placed with the filter paper in a small beaker, and if 5 grammes of a steel containing 0·05 per cent. of phosphorus had been taken for the assay, is treated with 30 cubic centimetres of a solution containing 12 grammes of sodium hyposulphite to 1 litre of water. The beaker is then heated to nearly a boiling temperature in a water-bath for half-an-hour, occasionally stirring its contents. The solution so obtained is compared with a standard solution obtained in a similar manner, as in the Eggertz carbon test.

The method is of considerable accuracy, especially in view of the fact that an excess of molybdic acid in the precipitate only produces a slight yellowish tinge with sodium hyposulphite solution, which does not affect the results to any appreciable extent.

The Elimination of Arsenic in the Determination of Phosphorus.—Mr. E. D. Campbell * adds 2 grammes of oxalic acid to the hydrochloric acid solution of the ore, and then evaporates the solution to dryness. The arsenic acid is reduced by the oxalic acid to arsenious acid, and volatilised as chloride on the evaporation with strong hydrochloric acid. The residue is then taken up with hydrochloric acid, filtered, and the phosphorus determined in the ordinary manner.

The Determination of Sulphur.—Mr. A. G. Rossi † discusses the various methods adopted in ironworks for the determination of this element in iron and steel. He gives the following modification adopted in Eastern France and Alsace-Lorraine:—From 5 to 10 grammes of the metal are dissolved in hydrochloric acid in the ordinary manner. The sulphuretted hydrogen is passed into Liebig tubes containing bromine and hydrochloric acid. When gas ceases to be evolved

* *Journal of Analytical Chemistry*, vol. ii. p. 370.
† *Iron Age*, vol. xlvii. p. 528.

a current of carbonic anhydride is passed through the whole apparatus, and the contents of the tubes are transferred to a porcelain dish. The tubes are well washed, and sodium carbonate is added cautiously to convert the sulphuric acid present into sodium sulphate. The solution is then evaporated to dryness, the residue moistened with a few drops of hydrochloric acid, water added, and the solution filtered. The precipitation is then effected by barium chloride in the ordinary manner.

The Determination of Manganese.—The German Iron and Steel Institute has instituted an examination of the various methods for the determination of manganese, and the results of these determinations are now published.* Dr. M. A. von Reis states that both the permanganate method, as modified by Wolff, and the chlorate method, modified by Ukena, gives good results provided the analyses are effected in identically the same manner as the standardising, but they give too low results if calculated according to the formula.

As a consequence of this report the committee recommends both methods for practical use, but considers neither to be sufficiently satisfactory to permit of its being definitely accepted as a standard method. The two methods are as follows:—

Wolff's Permanganate Process.—In this process all the manganese must be in the manganous condition, and all the iron be in the ferric form, in a hydrochloric acid solution. The ferric oxide is then precipitated by stirring in zinc oxide, when the manganese may be determined by a permanganate solution in the presence of the iron precipitate, the titration being effected at a temperature of about 80° C., the permanganate being added until the solution is coloured red.

The Ukena Chlorate Method.—This method depends on the fact that if manganese salts are boiled with nitric acid and potassium chlorate all the manganese is thrown down as peroxide. The precipitate contains small quantities of iron, which renders it unfit for direct weighing but does not affect its determination volumetrically.

Both these methods, which have already been referred to in this *Journal*, are described at considerable length.

Mr. A. J. Rossi,† in considering the various methods in practical use for the determination of manganese in iron and steel, gives the following descriptions:—

* *Stahl und Eisen*, vol. xi. pp. 373–385.

† *Iron Age*, vol. xlvii. p. 528.

Colorimetric Method.—0·0695 gramme of pure Mn_3O_4 is dissolved in hydrochloric acid and the solution evaporated to dryness. The residue is moistened with 10 cubic centimetres of nitric acid at 24° Baumé, and 100 cubic centimetres of sodium metaphosphate solution, 10 per cent. strong, is added. Fifteen grammes of calcium carbonate, finely pulverised, is then put in suspension in the liquid, stirring all the time, and finally the liquid is diluted to a bulk of 500 cubic centimetres; thus 1 cubic centimetre of the solution contains 0·0001006 gramme of metallic manganese. The pink liquor is filtered and poured into cylindrical glasses of as uniform a diameter as possible, correctly graduated to 50 cubic centimetres, the divisions giving the 0·5 cubic centimetres. This series of glasses furnishes what is called the scale. Into the first one 50 cubic centimetres of the pink solution are filled and no water added; these 50 cubic centimetres then contain $50 + 0·0001 = 0·005$ gramme of metallic manganese. If then 0·25 gramme of a sample to be analysed has been treated and has furnished 50 cubic centimetres of a solution of the same colour as this preceding standard solution, it corresponds in the sample analysed to 0·005 gramme of metallic manganese in 0·25 gramme of the substance, or to 2 per cent. of manganese. By filling a series of these standard bottles with solutions of different strengths a series of any desired percentage character is obtained.

In making the determination, 0·25 gramme or more is dissolved in 3 or 4 cubic centimetres of hydrochloric acid; the solution is evaporated to dryness, the residue moistened with a few cubic centimetres of nitric acid of 25° Baumé, and 30 cubic centimetres of a 10 per cent. solution of sodium metaphosphate is added. About 2 grammes of finely pulverised calcium carbonate is then put in suspension in the liquid, stirring vigorously for some time; when fumes of chlorine gas begin to be given off, the liquid is diluted to a bulk of 50 cubic centimetres. The solution is filtered in glasses graduated to the half-cubic centimetre, and allowed to stand a few hours. The colour is then compared with that of one of the standard solutions, the nearest to it in shade, and the percentage of manganese is obtained with a sufficient approximation.

It may sometimes happen that, when the sodium metaphosphate solution is added, an abundant precipitate of iron phosphate is formed. In that case this precipitate should be crushed with a glass rod to promote its being redissolved, the liquid diluted to 50 cubic centimetres as before and filtered. A solution may also precipitate after filtration.

In this latter case, as well as in the preceding, the operation is concluded as follows :—The filtrate in both cases is measured, 20 cubic centimetres of a 20 per cent. solution of metaphosphate and 3 to 4 cubic centimetres of nitric acid of 25° B., are added to it, and the mass is stirred vigorously with a glass rod; when the precipitate is redissolved the volume is completed to 100 cubic centimetres. Half of this quantity is then taken to compare its shade to that of the standard solutions as before, but the percentage of manganese thus found is doubled.

Volumetric Method.—The method used is that known as "Pattinson's Method." It is based on the precipitation of manganese as MnO_2 from a solution of $MnCl_2$ by calcium hypochlorite in presence of ferric chloride, the presence of this latter salt or zinc chloride being necessary to prevent the precipitation of manganese oxide in a lower state of oxidation than MnO_2. As practised at Continental works it differs, however, in several details from the method generally described under this name, and as it is the one most generally adopted for manganiferous ores, spiegeleisen, ferro-manganese, steel, iron, and even manganiferous slags, when the colour method is not followed, either on account, for instance, of large quantities of manganese present or for any other reason.

It is necessary for the accuracy of the method that there should be at least as much iron or zinc in the solution as manganese, and an excess of either iron or zinc is not in any way detrimental to the success of the operation. As is well known, several standard solutions or reagents are required.

1. *Solution of Calcium Hypochlorite.*—It is obtained by dissolving 15 grammes of ordinary bleaching powder in one litre of water. The salt contains about 35 per cent. of available chlorine. The solution is allowed to settle, and kept in bottles for use.

2. *Calcium Carbonate.*—It must be very finely pulverised; in that state it can be put in suspension in the liquid to which it is added. It can be prepared directly by precipitating a solution of calcium chloride by sodium carbonate at a temperature of 90° C., the presence of a slight excess of calcium chloride being considered as important. The precipitated carbonate is washed and carefully dried.

3. *Ferrous Sulphate Solution.*—It is so prepared as to contain about 1 per cent. of iron. It is obtained by dissolving 53 grammes of crystals of ferrous sulphate in a mixture of 1 part of sulphuric acid of 66° Baumé and 3 parts of water, the liquid having a total volume of 1 litre.

4. *Standard Solution of Potassium Bichromate.*—100 cubic centimetres

of this solution corresponds to 1 gramme of iron. It is the same as is used for the determination of iron in iron ores.

The Volumetric Determination of Manganese.—G. Vortmann * employs a method for this purpose which consists in oxidising the manganese in the presence of an alkali by a standard iodine solution, and determining the quantity of iodine required to convert the MnO to MnO_2, in the presence of alumina or ferric oxide. The excess of iodine is determined in the ordinary manner by a standard sodium hyposulphite solution.

Mr. T. Moore † describes a method for the volumetric estimation of manganese, in which the metal is oxidised, preferably by potassium chlorate, into the violet-coloured manganic metaphosphate, and is titrated with a reducing agent till the colour disappears. The substance is dissolved and the solution is concentrated to about 2 to 3 cubic centimetres; 10 to 20 cubic centimetres of a syrupy phosphoric acid, specific gravity 1·75, are added, and also a few crystals of potassium chlorate. The mixture is warmed till chlorine disappears. The solution is then diluted and titrated with ferrous sulphate, or a known quantity of the latter may be added, and the excess determined volumetrically with potassium permanganate. Chromium is the only metal which interferes with the reaction; cobalt gives a coloration which may be masked by the addition of nickel salts.

F. Moldenhauer ‡ modifies the Volhard method, in that hydrochloric acid solution (oxidised by nitric acid) is almost neutralised with soda, the ferric oxide thrown down by zinc oxide, a few grammes of ammonium sulphate added, and the solution heated, the titration being then effected with the permanganate.

The Determination of Aluminium.—In order to determine the aluminium in aluminium-steel A. Ziegler § dissolves 5 to 10 grammes of the metal in hydrochloric acid, evaporates to dryness, takes up with hydrochloric acid, and filters. The filtrate is then reduced with a solution of sodium hypophosphite, potassium sulpho-cyanide showing the end reaction, the alumina is precipitated by stirring in a slight excess of zinc oxide, the precipitate is filtered off, dissolved in hydrochloric acid, and precipitated. The precipitate is then redissolved in hydrochloric

* *Berichte der deutschen chemischen Gesellschaft*, vol. xxiii. p. 2801.

† *Chemical News*, vol. lxii. p. 67.

‡ *Chemiker Zeitung*, 1891, p. 13.

§ *Dingler's Polytechniches Journal*, 1890, p. 526.

acid, and the alumina precipitated by ammonia. After ignition it may be freed from impurities by long-continued fusion with sodium carbonate, dissolving and reprecipitating either by ammonia or by a current of carbonic anhydride. The precipitate, to insure a still greater degree of purity, may be redissolved in hydrochloric acid, and then finally precipitated by ammonia and ammonium chloride. As the ammonium chloride solution, if it is heated for any length of time, may become acid, although smelling strongly of ammonia by the decomposition of the ammonia salt, the author adds a few drops of litmus tincture before effecting the precipitation of the alumina, and then boils the solution in a porcelain dish until the alumina, which is at first of a pure blue colour, begins to show a violet tinge. By this means any solution of the precipitate by the ammonia liberated, or by any hydrochloric acid that may have formed, is avoided.

Ferro-aluminium is treated in the same way, except that instead of dissolving direct in acid, 0·5 gramme of the filings is fused with sodium bisulphate.

For the determination of small quantities of aluminium in iron or steel, A. Carnot * takes 10 grammes of the metal and dissolves it in hydrochloric acid in a platinum capsule. The solution is diluted and filtered off from the insoluble silica and graphite. Free acid is nearly neutralised by ammonia, and then with sodium bicarbonate, sodium thiosulphate is then added. When the violet coloration has disappeared and the ferric salt is all reduced, 2 to 3 cubic centimetres of a saturated solution of sodium phosphate and 20 centimetres of a solution of sodium acetate are added. The solution is then boiled for about forty-five minutes till sulphurous acid has disappeared. The slight precipitate which is formed contains aluminium phosphate mixed with sulphur, and a little silica and ferric phosphate. This precipitate is dissolved in dilute hydrochloric acid, evaporated to dryness, and kept at 100° C. for one hour to render the silica insoluble. The residue is then extracted with dilute acid, and the process is repeated as before, by which means all the iron is eliminated and the remaining precipitate consists of pure aluminium phosphate. It is ignited and weighed as $P_2O_5Al_2O_3$ containing 22·45 per cent. of aluminium. The operation only requires a few hours, and gives accurate results.

The Determination of Copper.—Dr. M. A. von Reis † discusses the methods for the determination of copper in iron and steel. The

* *Bulletin de la Société Chimique de Paris*, vol. v. p. 139.

† *Stahl und Eisen*, vol. xi. p. 238

use of sulphuretted hydrogen for this purpose is, the author observes, not to be recommended for various reasons to which he draws attention. It is much better to employ ammonium sulpho-carbonate, as this possesses, when compared with sulphuretted hydrogen, the great advantage that the precipitate forms immediately and may be filtered off in a quarter of an hour. It is not so easily oxidised as copper sulphide, and on ignition yields a pure oxide.

When pig iron is dissolved in hydrochloric acid a portion of the copper it contains remains in the undissolved residue, and to such an extent is this the case that in a high-percentage spiegeleisen or in ferro-manganese up to a half of the copper may remain undissolved. To avoid this, hydrogen peroxide should be added to the solution. The ensuing reduction should be effected, as Reinhardt has proposed, with sodium hypophosphite.

The following are details of the method used by the author:—Dissolve 10 grammes of iron in 50 cubic centimetres of water and 100 of strong hydrochloric acid in a large beaker; when the solution is complete add 30 cubic centimetres of hydrogen peroxide, and then heat for ten minutes to eliminate the excess. Then add 5 grammes of crystallised sodium hypophosphite and heat to boiling. In a few minutes the reaction is completed. The solution is now diluted with hot water to a bulk of from 600 to 700 cubic centimetres, and 10 cubic centimetres of ammonium sulpho-carbonate are stirred in. The dark brown copper precipitate rapidly deposits itself, and may be filtered off at once. For washing, water should be used which contains 20 cubic centimetres of the ammonium sulpho-carbonate and 20 cubic centimetres of concentrated hydrochloric acid to the litre, finally washing with water alone. Then burn and weigh. The results are very accurate.

Separation of Iron, Cobalt, and Nickel.—G. A. Le Roy * uses an electrolytic method for the separation of iron, manganese, nickel, and cobalt. To the solution in sulphuric acid a small quantity of citric acid and an excess of ammonium sulphate and ammonia is added. With a current from two Bunsen cells the manganese deposits at the positive pole, iron, cobalt, and nickel at the other pole. The deposit of these three metals is rapidly washed, and is then placed in a strongly ammoniacal solution of ammonium sulphate. With a weaker and

* *Comptes Rendus de l'Académie des Sciences*, vol. cxii. pp. 722–723.

reversed current the metals dissolve. The nickel and cobalt redeposit at the negative pole, and the iron remains in the solution as a precipitate of ferric hydrate, as citric acid is now absent.

II.—*ANALYSIS OF IRON ORES AND SLAG.*

The Determination of Manganese.—Mr. A. J. Rossi * gives the following description of "Pattinson's" method for the determination of manganese in manganiferous iron ores. These contain generally from 10 to 25 per cent., and even more, of manganese, and at least 20 per cent. of iron. One gramme of finely-pulverised and dried ore is dissolved, heat being applied to promote the action, in about 10 cubic centimetres of fuming hydrochloric acid. The solution is made in a large beaker, of a capacity of not less than 700 cubic centimetres, covered with a watch-glass. When it is completed the cover and the sides of the beaker are rinsed with cold water; then pulverised or precipitated calcium carbonate is gradually added, stirring all the time, until the liquid assumes a slight reddish tint, which is a sign that the free acid is saturated. The liquid is then acidified by the addition of 5 to 6 drops of hydrochloric acid, and then about 100 cubic centimetres of calcium hydrochlorite are added. The temperature of the liquid is brought up to 70° or 80° C. by the addition of a sufficient quantity of boiling water. Two and a half grammes more of calcium carbonate are then added, stirring all the time, until all the carbonic anhydride has been evolved. The precipitate of manganese and iron oxides is allowed to settle, when it will be usually found that the supernatant liquid is colourless. If calcium hypochlorite has been used in excess the supernatant fluid is sometimes of a faint pink colour, due to the presence of small quantities of permanganic acid. Should this be the case a little alcohol is added, drop by drop, until the colour has entirely disappeared. If the right quantity of hypochlorite has been added the solution smells decidedly of chlorine gas. If it does not the presence of this element in the free state must be ascertained by means of the proper test papers (iodide of potassium and starch). It is important to the success of the operation that the free acid be completely neutralised, and for this reason the second addition of calcium carbonate to the liquid cannot be dispensed with. The precipitate is

* *Iron Age*, vol. xlvii. pp. 528–529.

thrown on a tared filter and washed with cold water until the washings cease to give the reaction of chlorine to the proper reagents. The washing must be conducted rapidly; a quarter of an hour ought to be enough to complete it. Instead of the hypochlorite solution 50 cubic centimetres of water saturated with bromine has been used; in this case there is no necessity to add a few drops of hypochlorite after the first neutralisation by calcium carbonate, but here too it is essential to add calcium carbonate a second time to neutralise completely any free acid which may be present in the liquid. One hundred cubic centimetres of a solution of ferrous sulphate are then poured into the original large beaker of 700 cubic centimetres in which the first solution has been obtained, and to the sides of which beaker almost invariably small particles of the first precipitate remain adhering. The filter with its contents is transferred to this beaker now containing the ferrous solution, which dissolves readily the precipitates even in the cold. The manganese oxide transforms a part of the ferrous salt to ferric sulphate. The liquor is largely diluted to 500 or 600 cubic centimetres and the quantity of ferrous sulphate not transformed into ferric sulphate ascertained by a volumetric determination of the iron by means of the standard solution of potassium bichromate.

It is essential to determine exactly the quantity of iron contained in the ferrous solution added just before using it, even if it has been titrated previously, as it alters rapidly; and as the paper of the filter may have a reducing action (though it is possible to use paper not having such action), it is safer when titrating the ferrous solution by potassium bichromate to add to the liquid a filter of the same size and paper as the one used for filtration. The determination of the manganese is thus effected indirectly.

F. G. Myhlertz * mixes 0·5 gramme of the finely-powdered ore with 5 grammes of a mixture of three parts of sodium carbonate and one part of potassium nitrate, dissolves in boiling water, and, without filtering, adds 3 cubic centimetres of alcohol to reduce the permanganate. The solution is then filtered, the precipitate well washed, and the manganese determined by the ferrosulphate volumetric method.

The Determination of Titanium.—For the quantitative determination by Weller's method of titanium in iron ores, Mr. W. A. Noyes † mixes 0·1 gramme of the finely-powdered mineral with

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 13.
† *Journal of Analytical and Applied Chemistry*, January 1891.

0·2 gramme sodium fluoride in a platinum crucible. Cover with 3 grammes of sodium bisulphate and fuse carefully in a platinum crucible till sulphuric acid comes off. Dissolve in cold water, filter, and wash till the bulk is about 30 cubic centimetres. To the solution add one cubic centimetric of hydrogen peroxide and a few centimetres of dilute sulphuric acid. The colour is then compared with a standard solution made by dissolving titanic anhydride in sulphuric acid. The colour in the original solution due to the iron present should be matched by adding an iron salt to the standard. This method works excellently with magnetite and other iron ores.

C. Lüdeking * suggests the following method for the rapid detection of titanic anhydride even when present in very small quantity. The substance is dissolved in a very small sodium carbonate bead, and this is heated in the inner flame of a Bunsen burner until all the sodium has been volatilised; the copper-red scales of cyanonitride of titanium —$3\ Ti_3N_2 + TiCy_2$—may then be observed if titanium is present in the substance examined. The flame should be slightly luminous.

The Analysis of Blast Furnace Slag.—R. Namias † observes that the ordinary method for analysing a slag consists in fusing 1 gramme of the powdered slag with fusion mixture, taking up with water acidulated with hydrochloric acid, evaporating to dryness to render the silica insoluble, taking up with hydrochloric acid and filtering, dividing the filtrate into two parts, determining the iron in one and precipitating the other with acetate, and afterwards separating the manganese with bromine, and then determining the lime and magnesia in the filtrate with oxalate and with phosphate.

The author suggests that a modified method should be employed to determine the iron, aluminum, and manganese; the one he adopts is as follows:—After separating the silica divide the filtrate into two parts. In one of these determine the iron and the manganese volumetrically, and in the other precipitate the iron, aluminum, and manganese.

In the determination of the manganese the solution should not contain nitric acid, neither should there be too great an excess of hydrochloric acid. A little bromine is added to oxidise all the iron, the excess being boiled off. The solution is then almost completely neutralised with sodium carbonate, milk of zinc oxide is added, and the manganese determined by the Volhard method, which, it may be remem-

* *Liebigs Annalen*, vol. ccxlvii. p. 122.

† *L'Industria, Rivista tecnica ed economica*, vol. v. pp. 153–154.

bered, is based on the discovery of Guyard, that if to a neutral or but slightly acid solution of a manganese salt a solution of potassium permanganate is added, all the manganese is precipitated in the form of a hydrate of the binoxide, the permanganate being similarly reduced according to the formula—$3MnO + Mn_2O_7 = 5MnO_2$.

The same solution which has served for the determination of the manganese serves also for the determination of the iron. Dissolve the precipitate by adding to the solution some hydrochloric acid, afterwards neutralising with some sodium carbonate until there is but little free hydrochloric acid left. The iron is then determined by the ordinary iodide-hyposulphite method.

To the other half of the original solution an excess of sodium bicarbonate is added. This causes the precipitation of the iron, alumina, manganese, and some lime and magnesia. Some bromine is then added to the solution, and the whole heated for about half-an-hour, adding bromine if the solution decolorises. The operation is to completely oxidise the manganese. The solution is then acidified with acetic acid and boiled, in order to completely dissolve any lime and magnesia which may have been precipitated as carbonates. The acetic acid has no action on the manganese binoxide, provided certain organic substances are absent. By adding an excess of ammonia and some ammonium chloride to the solution all the iron and alumina is precipitated. After filtering the precipitate is ignited, and should then consist of a mixture of Mn_3O_4, Fe_2O_3, and Al_2O_3. Both the iron and the alumina having been previously determined, the difference in weight represents the alumina. The lime and magnesia are precipitated from the filtrate in the ordinary manner.

III.—*FUEL ANALYSIS.*

The Estimation of Sulphur in Coal.—Mr. T. Neilson * gives the results of several experiments made to determine the best way of determining sulphur in coal. The coal was mixed with calcium carbonate or with magnesia, and ignited at a dull red heat, extracted with water or hydrochloric acid, and the sulphur determined with barium chloride in the usual manner. Fusion mixture and subsequent oxidation with bromine water was also tried, and also a new process as

* *Chemical News*, vol. lxiii. p. 192.

follows:—Mix 1 gramme of coke with 2 grammes of sodium carbonate and 0·5 gramme of manganese carbonate, ignite at a dull red heat in a platinum dish for one hour, then fuse, cool and treat with water, add 20 cubic centimetres of hydrochloric acid, evaporate to dryness, take up with hydrochloric acid and water, filter and precipitate in the usual manner. Satisfactory results are obtained.

IV.—*GAS ANALYSIS.*

Gas Analysis.—W. Thörner * describes an apparatus for the rapid determination of oxygen and carbonic anhydride in furnace gases. The description of the arrangement of the various absorption tubes is illustrated by a sketch of the apparatus.

* *Stahl und Eisen*, vol. xi. pp. 321–323.

STATISTICS.

CONTENTS.

I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the official reports of Her Majesty's Inspectors of Mines the production of coal in the United Kingdom in 1890 amounted to 186,614,288 tons. The production during the previous year was 176,916,724 tons.

The total quantity of iron ore raised was 13,780,767 tons, of which 8,117,476 tons consisted of stratified ironstone and 2,648,267 of iron ore from mineral veins. In 1889 the total output was 14,546,105 tons.

The total number of works in operation in 1890 was 156, representing 748 blast furnaces, of which $413\frac{9}{12}$ were in blast. In making the 7,904,214 tons of pig, 19,213,916 tons of iron ore, inclnding cinder, were used, and 16,168,538 tons of coal. Compared with the previous year these figures show an increase of 6 in the number of works in operation, a decrease of 21 furnaces and 31 in blast, a decrease of 418,610 tons produced, and a decline of 470,032 tons of ore used and 598,156 tons of coal.

The value of the pig iron obtained from British and foreign ore in 1890, according to the average selling price for the year, is £24,140,786, of which £14,808,884 is due to pig iron from British ore.

In 1890, 3,190,542 tons of hæmatite pig iron were made, as compared with 3,151,130 tons in 1889; 4,483,677 tons of ordinary and

basic pig iron as against 4,986,233 tons, and 229,995 tons of spiegeleisen, ferro-manganese, chrome, and silicon iron, as compared with 185,461 tons in the previous year. Of the total production, 1,145,268 tons were exported, leaving 6,758,946 tons available for home consumption.

Petroleum Imports into Great Britain.—Messrs. H. Faunck & Co. state * that the imports of refined petroleum oil to England from America and Russia were as follows:—

	1890. Barrels.
America	1,355,590
Russia	771,227
Total	2,126,817

Death-Rate in Different Industries in England.—The annual death-rate per thousand persons employed in England in the following industries is stated to be: †—

	Age 25 to 45 Years.	Age 45 to 65 Years.
Average for the whole country	10·16	25·27
Minimum	4·64	15·93
Maximum	22·63	55·30
Coal miners	7·63	25·11
Iron ore miners	8·05	21·85
Tin miners, Cornwall	14·77	52·69
Cutlery makers	11·70	34·42
Boiler makers	9·27	26·65
In iron and steel works	8·36	22·85
Average for metal workers	8·80	25·03

II.—*AUSTRALASIA.*

Coal-Mining in New South Wales.—The coal basin around Newcastle, in New South Wales, has been proved to extend 200 miles to the south, 800 miles to the north, and in places up to 250 miles from the coast. The exact extent of the basin cannot yet be defined, as but very little prospecting has been done. Coal was discovered nearly one hundred years ago, and was for some time worked by convict labour. In 1826, however, a company was formed, and took up a million acres of land, together with the Government mines. For some time there

* *The Engineering and Mining Journal*, vol. li. p. 286.
† *Ibid.*, vol. l. p. 576.

was a monopoly in the production, but this was surrendered in 1847. The report of the Department of Mines show that fifty-six properties or companies are now working, giving employment to 7559 men in the Newcastle district. To the south of Sydney there are ten companies employing 2056 men, and in the west there are seventeen properties employing 653 men. In addition, there are four companies working kerosene shale. During 1889 the output in the Newcastle district was 2,624,347 tons, each person underground averaging 442 tons per year. The coal measures worked in the district are divided into three series, the Newcastle, the Greta, and the Tomago. The seams lie nearly level, and average 8 to 10 feet of workable coal. According to Professor Liversidge, an average assay of samples from forty-two collieries shows :—

Specific Gravity.	Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.	Sulphur.	Coke.
1·298	2·45	35·51	54·29	6·80	0·88	61·14

Prior to 1829 the output of Newcastle was estimated to have been 50,000 tons. Since then the production from that and other districts has risen steadily. In 1880 the production in New South Wales was nearly one and a half million tons, and in 1889 it amounted to 3,655,632 tons, the total up to the end of that year being 45,335,012 tons. The trade in coke is small, 8438 tons being exported in 1889, a quantity over 6000 tons less than in the previous year.*

Coal Production of New Zealand.—According to the Report of the Registrar General of New Zealand, the approximate total output of the coal-mines to the end of 1889 amounted to 5,819,277 tons. As far as surveys have been made, it is estimated that the brown-coal fields contain about 500,000,000 tons, the pitch-coal fields contain the same amount, whilst the bituminous coal fields contain 200,000,000. As the bituminous coal is found on the west coast of the Middle Island, and partly in somewhat inaccessible districts, the estimate is considered to be very much short of the actual quantity that may be found to be available.

III.—*AUSTRIA-HUNGARY.*

The Iron Trade of Styria.—There were in Styria in 1889, 27 charcoal blast furnaces, and 3 coke blast furnaces, 19 of the former being in blast for 732 weeks, and 2 of the latter for 104 weeks. The charcoal

* *Engineering*, vol. l. pp. 763–765.

furnaces made 21,600 tons of grey pig iron, 1573 tons of mottled, and 71,012 tons of white. The coke furnaces made 44,969 tons of pig iron, 25,124 tons of which was white pig iron, and the rest, with the exception of 30 tons, grey pig iron.

The open-hearth furnaces with acid linings produced 29,608 tons of ingots, and those with basic linings 28,322 tons. The Bessemer works made 24,450 tons of steel. The rails made amounted to 34,373 tons, other products reaching a total of about 100,090 tons, 5699 of which was crucible steel, and 109 cement steel.*

The Transport of Iron Ore in Hungary and Prussia.—F. W. Lürmann † compares the cost of transport of iron ore in Hungary and Prussia, and gives in tabular arrangement the railway charges for various distances. He shows how greatly it would be to the advantage of the iron industry of the Ruhr district if the tariff rates for iron ore transport should be reduced.

The Mining Industry of Austria.—At the close of the year 1889 there were in Austria 27,299 allocations, an increase of 6·86 as compared with the previous year. Of these rather more than 75 per cent. related to coal and 9½ per cent. to iron ore.

In *Bohemia* there existed 13,160 valid allocations at the commencement of 1890. Of bore-holes, three had been put down by the Anglo-Bohemian Company in the Schlan mining district. That put down at Lahna met with a 3-foot seam of coal at a depth of 180 feet, the other two were sunk to depths of nearly 300 feet each without any successful result. Another coal-seam was struck by boring at Studnoves. In the Mies district three borings were made to depths of over 1000 feet without meeting any payable seam, and another which had been sunk to twice this depth had to be abandoned owing to a breakage of the rods. An 8-foot seam was struck in this district by a bore-hole at a depth of 1200 feet.

In *Lower Austria* various successful borings were made during 1889. A seam of lignite 34 feet in thickness was struck at a depth of rather more than 600 feet near Solenau.

In *Silesia* a bore-hole was sunk to a depth of 700 feet in Carpathian sandstone near Skotschau, in search of petroleum.

A number of other bore-holes were sunk elsewhere in Austria, and some to considerable depths, mostly, however, without success.

* *Stahl und Eisen*, vol. x. p. 1082.

† *Ibid.*, vol. xi. pp. 197–201.

The mining claims already referred to had a total area of 422,152 acres; 79·98 per cent. of this pertained to coal workings and 10·15 to iron ore mines.

The engines employed in pumping and for hoisting purposes numbered 1158, of which 1030 were in collieries and lignite mines. The total horse-power of these engines amounted to 58,097.

The blast furnaces erected numbered 124, and the Bessemer converters 21.

The workpeople employed at the collieries numbered 45,810, and at the lignite mines 35,254, an increase of 4000 over the total of 1888. Iron ore mining gave employment to 4961, and ironworks to 11,387.

The accidents at collieries numbered 171, with 86 deaths; at lignite mines, 203, with 77 deaths; and at iron ore mines 18 accidents, with 7 deaths. The fatal accidents were slightly in excess of those of the previous year. There was one death for every 99,917 tons of coal raised, one for 179,816 tons of lignite, and one for every 159,308 tons of iron ore.

The production of petroleum amounted to 71,659 tons, an increase of 10·44 per cent. over the output of the previous year. The 204 active undertakings gave employment to 3191 workpeople.

Ozokerite was mined at eighty-four places. The production was 7560 tons, 6004 workpeople being employed.

Details are also given as to the general health of the people engaged in the various branches of mining and metallurgy.*

The Iron Trade of Hungary.—The production of pig iron in Hungary † during 1890 amounted to about 280,000 tons, the greater part of which was made at the following works:—

	Tons.
1. The works of the State Railway Company	75,846
2. The works of the Rima-Tarjan Ironworks Company	58,322
3. The Royal Hungarian State Ironworks	57,077
4. The works of Count E. Andrássy	22,500
5. The works of the Kronstadt Mining and Smelting Company	11,076
6. The works of the Krompach-Hernad Company	4,800
7. The Concordia Ironworks	9,000
Total	238,621

The production of direct castings was about 35,000 tons.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 551–553, 563–566, 574–577, 583–586.

† *Der Ungarischer Metallarbeiter*, through *Stahl und Eisen*, vol. ix. pp. 345, 346; *Pester Lloyd*, February 24, 1891.

The various works making iron and steel in Hungary in 1890 were working at their maximum capacity. The total quantity of iron and steel made is estimated at 1,974,603 tons. The total existing acid Bessemer converters was six, two of which were held in reserve, and of basic converters, three. There were also two small converters for Bessemerising on a small scale. The open-hearths numbered eleven, and the puddling furnaces exceeded forty double furnaces. There was one crucible steelworks. The maximum number of work-people employed at any one works numbered 2615, that of the Rima-Murány-Salgó-Tarjan Company. The State Ironworks gave employment to 2400 hands, and the ironworks of the State Railway Company at Diósggör, to 1613.

Statistics are published * relating to the production of the mines and smelting works of Hungary in the year 1889. The production was as follows:—

	1889.	1888.
	Metric Tons.	Metric Tons.
Pig iron	225,940	194,085
Foundry pig iron . . .	12,860	10,021
Coal	937,452	850,691
Lignite	1,950,226	1,874,201
Briquettes	22,797	23,390

Condition of Miners in Hungary.—The number of persons employed in the mines of Hungary is 35,533, of whom 29,830 are men, 5000 are boys from twelve to sixteen years old, and the remainder are women. The average daily wages earned in the mineral mines are seventeen to nineteen pence, and in the coal mines, twenty-five to thirty-one pence. In the mineral mines work is usually carried on at night, but if day work is done, there are three shifts of eight hours. In coal-mines work is usually done in two twelve-hour shifts, with an allowance of two hours in each shift. The miners are usually lodged in houses built by the companies, who also sometimes supply necessaries at cost price. Strikes are rare and are of short duration.†

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 577.

† *Revue Industrielle*, through *The Engineering and Mining Journal*, vol. li. p. 381.

IV.—*BELGIUM.*

Iron Trade Statistics.—The Belgian production of iron and steel in 1890 and 1889 was as follows:—

	1890.	1889.
Foundry pig iron	73,312	89,097
Forge pig iron	530,225	606,785
Bessemer pig iron	178,421	152,378
Totals	781,958	848,260
Rails and plates	121,251	143,506
Various descriptions	385,707	476,548
Total manufactured iron	506,958	620,054
Cast steel, ingots, &c.	239,266	248,641
Forged steel, rails, plates, &c.	216,129	236,186

Imports and Exports.—The following table shows the Belgian iron trade imports and exports for 1890 and 1889:—

	Imports.		Exports.	
	1890.	1889.	1890.	1889.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore	1,644,421	1,805,210	...	157,327
Pig iron	250,952	243,190	11,309	14,513
Scrap iron	18,634	24,608	11,757	7,559
Wrought Iron—				
a. Wire	3,811	3,149	2,340	4,841
b. Rails	156	611	12,857	14,629
c. Sheets	1,859	2,054	45,679	56,165
d. Other kinds	10,089	11,664	217,960	257,352
Manufactured Iron—				
a. Nails	665	600	10,103	13,820
b. Other wrought iron manufactures	3,673	3,694	35,244	37,327
c. Castings	2,381	2,204	30,896	28,165
Cast steel	9,883	6,515	453	3,151
Steel rails	756	1,099	73,867	67,979
Steel sheets and wire	3,779	3,520	26,121	36,660
Wrought steel	1,053	1,318	8,983	8,395

The exports and imports of coal and coke were as follows :—

	Coal.		Coke.	
	1890.	1889.	1890.	1889.
	Tons.	Tons.	Tons.	Tons.
Exports . . .	4,537,718	4,257,694	1,062,980	1,220,325
Imports . . .	1,727,011	1,004,624	65,119	18,545

The Iron Trade of Belgium.—A graphic representation has been published * of the movements of the iron and coal markets of Belgium during the years 1888, 1889, 1890. Prices remained fairly constant during 1888 with a slightly higher tendency, rose a little in the earlier months of 1889, and increased enormously during the last quarter of that year, reaching a maximum about the end of the year. They remained at the high figures reached until about the end of March 1890, and then fell rapidly, almost reaching a normal level at the end of the year.

V.—*CANADA.*

Petroleum in Canada.—According to the report of the Inland Revenue Department there has been an increased production of petroleum as follows :—

	1890.	1889.	1888.
Barrels of 42 gallons	236,768	220,960	217,587
Cases of 20 gallons	44,196	38,344	23,928

Mineral Statistics of Nova Scotia.—According to an annual report † by Mr. E. Gilpin, jun., 1,984,001 tons of coal were raised in 1890 as compared with 1,756,279 tons in 1889. Coke was made to the amount of 36,738 tons in 1890, as against 35,565 tons in 1889. The production of iron ore in 1890 was 51,191 tons, and of manganese ore 266 tons.

Nova Scotia Coal.—The following table shows the imports of coal

* *Moniteur des Intérêts Matériels*, Dec. 14, 1890.

† Through *The Engineering and Mining Journal*, vol. li. p. 444.

by water into the ports of Montreal, Sorel, Three Rivers, and Quebec in 1889 and 1890.*

From	1890.	1889.
	Tons.	Tons.
Cape Breton collieries . .	470,218	359,031
Pictou collieries . . .	59,273	45,865
Great Britain	16,974	62,629
Total . .	546,465	467,525

The following table gives the sales of the chief collieries in the three coal-producing districts for 1890 :—

	Round Coal. Tons.		Slack. Tons.
Pictou County	158,772		90,085
Do.		164,370	
Do.		1,360	
Do.	22,464		10,113
Cumberland County . . .	311,399		72,552
Do. . . .		53,492	
Do. . . .		7,485	
Cape Breton	143,365		9,316
Do.	100,351		8,870
Do.	70,118		7,252
Do.	122,299		20,809
Do.	104,003		22,883
Do.	104,409		42,575
Do.	95,144		37,932

VI.—*CHINA.*

Iron and Steel Works.—Iron and steel works for the construction of steel rails for railways, steel for gun founding, and mercantile iron have been begun near Hanyang. The masonry for blast furnaces is being rapidly constructed, and machinery from England has been ordered. In February there were two locomotives at the works, and about three-quarters of a mile of railway laid. The works are situated on the River Han, and arrangements are being made to have a jetty on the Yangtze, a little above its junction with the Han. The ground will be raised 6 feet above the highest flood level of the Yangtze.

* *The Canadian Mining and Mechanical Review*, vol. x. pp. 2, 3.

It is contemplated, in the first instance, to turn out 100 tons of steel rails per day, and ultimately to increase the output to 200 tons a day. This is exclusive of mercantile iron and steel for guns. The ground to be covered by the ironworks is more than 30 acres. Good iron ore has been discovered at Huang Kang, about 15 miles down the river, and 20 miles inland.*

VII.—*FRANCE.*

Wages of French Coal-Miners.—The French Minister of Public Works has issued some statistics on the subject of coal-miners' wages in France. In 1888 the daily wage was just over 3s. The official record shows that the average during three years ending 1864 was about 2s. 1d. per man. In 1791 the average was only 1s. a day. Between 1860 and 1880 the output had advanced from 140 to 215 tons per year per head in consequence of improvements in working, but the market value of coal had decreased. In 1860 to 1864 the number of miners was 69,000, in the period 1885–1888 it had advanced to 103,000, and the average yearly wage per head amounted to £45.

M. Plichon has prepared statistics of the comparative daily wages in various European countries. In Prussia in 1887 it was 2s. 4d.; in Belgium, 2s. 3½d.†

Accidents in Coal-Mines.—P. Habets ‡ has tabulated and plotted in the form of curve the statistics of accidents in coal-mines in Great Britain, France, Russia, and Belgium. The statements in most cases reach back as far as 1851, and they show the production of coal, the total number of labourers employed on the surface and underground, the accidents from various causes, both underground and on the surface, as far as statistics are available. The plotted results are also made by means of shaded areas to show the various disposition of the causes of accidents. In all these countries except Prussia the death-rate per thousand has decreased owing to greater care and improved means of working. The increase in the latter country is ascribed to the rapid development which has necessitated the use of much unskilled labour.

* *Industries*, vol. x. p. 524.

† *The Iron and Coal Trades Review*, vol. xli. p. 440.

‡ *Revue Universelle des Mines*, through the *Engineering and Mining Journal*, vol. l. pp. 482, 483.

The Coal Question.—The coal question, especially in its relation with France, is discussed by G. Lavergne. The annual consumption of that country is about thirty-five million tons. Three and a half million tons are used for domestic purposes, and manufacturers employ some twenty-five million tons. In the case of manufactories there is generally a reserve of one month's supply, so that sufficient coal is above ground to last for about three months in case of sudden stoppage. The author deals also with the supply in other countries, and traces the effect on the production of the outside demand, affairs in Europe, speculation, and the behaviour of the workmen.*

VIII.—*GERMANY.*

Iron Trade Statistics.—The official provisional returns relating to the production of coal, iron ore, and steel in Germany, including Luxembourg, in 1890, are as follows:—

Materials.	1890.	1889.
	Metric Tons.	Metric Tons.
Coal	70,039,046	67,187,143
Lignite	19,012,481	17,601,466
Iron ore	11,409,625	11,002,187
Charcoal pig iron	24,141	24,927
Coke pig iron	4,613,098	4,499,631
Castings	981,853	949,937
Weld iron	1,454,131	1,640,800
Ingot iron	2,161,821	2,022,472

The total value was £47,810,000 in 1890, as compared with £42,452,000 in 1889.†

Production of Pig Iron.—The Imperial Statistical Department of Germany publishes the following statistics relating to the imports and exports of pig iron of Germany, including Luxembourg, in 1890.

	Imports.	Exports.
	Metric Tons.	Metric Tons.
Pig iron	384,953	116,876
Old iron and scrap	19,461	40,680
Totals	404,414	157,556

The imports thus exceeded the exports by nearly 250,000 tons.

* *Le Génie Civil*, vol. xxiii., pp. 90–92. † *Stahl und Eisen*, vol. xi. p. 428.

Provisional statistics show that the production of pig iron during 1890 amounted to about 4,563,000 tons, as compared with 4,387,504 tons in 1889.*

Iron-Mining in Saxony.—According to the return of the Central Chamber of Commerce for the German Empire in 1889, the only iron mines working in the Berggiesshübel district were those belonging to the firm of Gruson. The production amounted to 7501 tons, valued at £4605.†

IX.—*ITALY.*

Mineral Statistics.—The production of iron ore in Italy in 1889 amounted to 173,489 tons, 3668 tons less than in 1888.‡ Of this total, 153,497 tons, valued at £81,353, was Elba ore. The export of Elba ore in 1889 was 126,614 tons, as compared with 195,825 in 1888.

The blast furnaces in blast in 1889 numbered eleven, with a total production of 13,473 tons of pig iron, an excess of 1073 tons over the outturn of the previous year. The outturn of iron and steel amounted to 330,522 tons, an increase of 44,968 tons, the steel and iron bearing to one another the ratio of 87 : 100, as compared with 67 : 100 in 1888.

The production of the Terni Steelworks was 78,979 tons, an increase of 14,000 tons over 1888. The total value of the products of this works was £800,427 ; the consumption of fuel was 129,000 tons.

The ironworks of Liguria showed a diminution in the quantity of iron they produced in 1889 as compared with 1888 of about 5000 tons, but the outturn of steel increased by 20,000 tons.

Imports and Exports.—The imports into Italy during the year 1889 were as follows:§—

	Tons.
Coal	3,999,117
Petroleum	71,331
Pig iron	191,082
Iron and steel	309,245
Tinplates	8,475

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* *Stahl und Eisen*, vol. xi. p. 253.

† *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 417.

‡ *L'Industria*, vol. v. pp. 428–429.

§ *Industries*, vol. x. p. 463.

The exports during the same period were:—

	Tons.
Iron ores	183,281
Asphalt	4,825
Graphite	1,376

X.—*MEXICO.*

Mexican Imports.—The value of the imports of iron and steel manufactures and of machinery into Mexico for the year ending June 30, 1889, was as follows from the countries named:—

	United Kingdom.	United States.	France.	Germany.
	Dollars.	Dollars.	Dollars.	Dollars.
Iron and steel manufactures	337,595	815,225	107,050	227,516
Machinery	3,461	436,736	28,594	30,813

Most of the machinery imported is included under the heading "Free Goods," and this was of the following values: *—

	Dollars.
United Kingdom	2,050,826
United States	10,293,301
France	322,379
Germany	299,136

XI.—*RUSSIA.*

Mineral Statistics.—According to an official report just issued on the Russian iron and steel industry during the ten years of 1879–88, in 1888 there were under working in the entire Russian empire 612 iron-mines, and iron ore was further raised from 149 lakes. Of the former, no less than 522 were situated in the government of Ural, and of the latter, 132 in Finland. The total output of ore amounted to 1,381,000 tons, of which 42,000 tons consisted of lake ore. Compared with 1887 there is an increase of 75,500 tons. Naturally, the Ural shows the highest output, 778,000 tons. The number of foundries producing pig iron was 132, with 200 furnaces, producing 612,000 tons, of which quantity more than three-fourths was smelted with charcoal. Again, the Ural shows the largest output—nearly 400,000 tons. The

* *Report of the Bureau of Statistics of the United States Treasury Department*, through *Iron Age*, vol. xlvii. p. 927.

largest make at one works was 50,000 tons, viz., by the works of La Nouvelle Russie, in the government of Catherinoslaw, where coke is solely used in the smelting. Compared with 1887, the make of pig iron has increased by 52,000 tons, or nearly 9 per cent. During the period of 1879–88 the manufacture of pig iron in Russia has increased by 230,000 tons or 54 per cent. Up to 1886 the increase was slow, amounting only to some 90,000 tons, but since then there has been a rapid progress. The greatest increase, 41 per cent., occurred in the district of Moscow.

In 1888, 173 works were engaged in the bar iron industry, the make amounting to 350,000 tons, an increase since 1887 of only some 4000 tons. The manufacture has greatly fluctuated in the different governments. The Russian bar iron industry shows but slow progress during the period 1879–80, the total increase being only 81,000 tons.

Like the bar iron industry, the Russian steel industry advanced insignificantly in 1888, the manufacture amounting to 211,000 tons, or only 3000 tons more than in 1887. The production has decreased as much as 37 per cent. in Finland, on account of the largest steelworks in that country being idle, but has increased in other provinces. At the works of the Muta-Bankowa Company, the increase of manufacture amounted to 3500 tons. During the decennial period referred to, the manufacture of steel in Russia fluctuated very much; for instance, 1880 shows a production amounting to 300,000 tons, whereas in 1885 it had declined to 180,000 tons. Of the quantity produced in 1888, 1100 tons were made by casting, 2300 tons by puddling, 49,500 tons by the Bessemer, and 154,000 tons by the open-hearth process, and 4100 tons by the Franche Comté process. The number of steelworks in the country was 32. The manufacture of steel rails amounted to 61,000 tons.

Finally, as regards the relations between the consumption and the iron required to be imported in Russia to cover the former, the country supplied in 1888, 90 per cent. of the pig iron required, 85 per cent. of the bar iron, and nearly 96 per cent. of the steel. The report also contains a table which shows in the most striking manner the effect exercised of late years by the steady increase of duties in Russia, viz., a falling off of imports and increase of production, particularly as regards pig iron. Thus in 1879 the production of pig iron amounted to 420,000 tons, and the imports to 180,000 tons, whereas after ten years of steadily increasing protection the relative figures were 612,000 tons and 73,000 tons.*

* *Iron*, vol. xxxvii. p. 385.

The Coal Industry.—A. de Keppen* states that there were in Russia, in 1888, 330 active collieries, which produced—

	Tons.
Coal	4,627,901
Anthracite	516,452
Lignite	41,455
Total	5,185,808

By districts the output was as follows:—

	Tons.
Poland	2,413,711
Donetz	2,240,126
Central Russia	276,248
Ural	208,962
West Siberia	16,550

The two first districts have doubled their output since 1879, while that of Central Russia has diminished by one-half.

The exports of coal from Russia in 1889 amounted to 14,429 tons, and the imports to 1,871,833 tons of coal, and 197,176 tons of coke.

Mineral Statistics of Finland.—According to the detailed report of the Finnish metal industries for 1888,† which has only recently appeared, the production of mountain iron ore in Finland is very small, only one mine being worked, producing 46 tons, but lake ore was raised in 1888 to the amount of 34,813 tons, valued at £13,000, from 132 lakes. Most of the ore required in the Finnish iron industry is imported. There were fifteen furnaces in blast, producing 19,300 tons of pig iron, valued at £65,000. The make of bar iron amounted to 3372 tons, valued at £30,000, and that of fine iron (including plates, rods, angles, mill bars, &c.) to 6672 tons, valued at £63,000. Of steel only 1348 tons were turned out, valued at £15,000; but of manufactured iron and steel goods of all kinds 2494 tons were produced, valued at £37,000, and of cast ware 4190 tons, valued at £38,000. The total number of hands employed in these industries was 17,534; but there were only eight accidents, one being fatal.

Compared with 1887 the production of lake ore has been increased by 4300 tons, this quantity being the largest raised since 1884; but the production of pig iron was less by 200 tons, owing to the idleness

* Circular 404 of the *Comité Central de Houillères de France.*

† *The Colliery Guardian*, vol. lxi. p. 498; *Stahl und Eisen*, vol. xi. p. 428.

of the great Dahlsbruk Iron and Steel Works, and for the same reason the bar iron production decreased by 120 tons. These decreases would be far larger if the make at other works had not been increased. The make of mill bars, too, has fallen off by 716 tons, and that of steel by 725 tons. In all, the iron and steel industry shows a falling-off of 2580 tons. In 1887 the Dahlsbruk Works produced 3440 tons.

XII.—*SPAIN.*

Exports of Iron Ore from Bilboa.—The exports of iron ore from Bilboa have been as follows * :—

Year.	Tons.
1878	1,224,730
1880	2,345,598
1885	3,295,982
1887	4,170,422
1888	3,580,425
1889	3,854,635
1890	4,272,918

XIII.—*SWEDEN.*

The Production of Iron.—The production of iron, according to the Society of Swedish Ironmasters,† during the last two years was as follows :—

	1889	1890.
	Tons.	Tons.
Pig iron	421,176	435,522
Blooms	228,546	227,786
Bessemer ingots	80,614	92,247
Open-hearth ingots	54,613	67,779

During the two years there have been in operation :—

	1889.	1890.
Blast furnaces	150	145
Bessemer converters	25	23
Open-hearth furnaces	23	26
Other furnaces	404	396

* *Revista Minera*, 1891, p. 16. † *Industries*, vol. x. pp. 150–151.

The exports during 1890 were as follows, as compared with those of 1889 :—

	1889.	1890.	During 1890. Decrease.	During 1890. Increase.
	Tons.	Tons.	Tons.	Tons.
Pig iron	79,175	59,931	19,244	...
Ingots	8,530	8,060	470	...
Blooms	15,596	12,991	2,605	...
Other hammered and rolled bars	200,244	185,468	14,776	...
Ends of bars	5,924	3,978	1,946	...
Wire iron	4,166	4,971	...	805
Plate iron	5,717	6,982	...	1,265
Nails	2,167	2,461	...	294
Iron ore	118,573	187,532	...	68,959

Coal.—The anthracite coal industry of Sweden, which is in the hands of seven operating companies only, greatly improved in the year 1889. The production for the five years ending with 1889 was as follows:—In 1885, 239,356 tons; 1886, 234,203; 1887, 232,398; 1888, 232,383; and in 1889, 256,628 tons. In 1889 some 5000 persons were employed in and about the mines, and only one life was lost through accident. At present but a small portion of the deposits is being worked, though a far more extensive development is expected to be made within a short time. The coal is found only in the extreme south of Sweden, in the province of Scania. The coals are of excellent quality for steam and similar uses, but being anthracite, and the mines being too distant from the iron districts, they cannot be expected to take an important position in the iron industry.*

Swedish Open-Hearth Furnaces.—E. G. Odelstjerna † publishes the following table relating to the open-hearth industry of Sweden :—

	Years. 1884.	1885.	1886.	1887.	1888.	1889.
Number of works	14	18	18	19	20	21
Number of furnaces	20	26	27	28	29	29
Total capacity of furnaces	70	103·5	112	137·5	146·5	150·5
Increase, per cent.	...	47·9	8·2	23·3	6·5	2·7
Ingots, outturn, tons	23,699	28,914	33,463	40,461	43,284	53,774
Increase, per cent.	...	22	16	21	7	24·2
Steel castings, outturn, tons	318	593	818	1,373	1,402	2,072
Increase, per cent.	...	86	55	68	2	47·8

* *Industries*, vol. x. p. 367.

† *Jernkontorets Annaler*, vol. xlv. No. 5.

The Nora Mining District, Sweden.—The annual output of iron ore in this district in 1889 was about 152,000 tons from eighteen mines. The mining costs amounted to from 3s. 4d. to 8s. per ton of ore. Dynamite and ammonia powder were the explosives employed. Two magnetic separators were in use, and these worked at a cost respectively of 1s. 9d. and 9d. per ton.*

XIV.—*UNITED STATES.*

Production of Pig Iron.—The production of pig iron in the United States in 1890 is stated by Mr. J. M. Swank in his annual report to have been as follows:—

Fuel Used.	Production. Tons of 2000 lbs. (Includes Spiegeleisen).		
	First Half of 1890.	Second Half of 1890.	Total for 1890.
Anthracite	1,227,195	1,221,586	2,448,781
Charcoal	314,427	389,095	703,522
Bituminous	3,566,153	3,588,572	7,154,725
Totals	5,107,775	5,199,253	10,307,028

The following table shows, in tons of 2000 lbs., the total production of pig iron during each of the years 1887–1890 in the several States:—

* *Jernkontorets Annaler*, 1890, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 10.

States.	Tons of 2000 lbs.			
	1887.	1888.	1889.	1890.
Maine	4,397	5,574	5,200	1,200
Massachusetts	11,114	13,248	7,751	5,531
Connecticut	21,741	21,644	24,143	22,552
New York	296,572	257,180	297,247	369,381
New Jersey	172,554	101,882	125,693	177,788
Pennsylvania	3,684,618	3,589,186	4,181,242	4,945,169
Maryland	37,427	17,606	33,847	165,559
Virginia	175,715	197,396	251,356	327,912
North Carolina	3,640	2,400	2,898	3,181
Georgia	40,947	39,397	27,559	32,687
Alabama	292,762	449,492	791,425	914,940
Texas	4,383	6,587	4,544	10,865
West Virginia	82,311	95,259	117,900	144,970
Kentucky	41,907	56,790	42,518	53,604
Tennessee	250,344	267,931	294,655	299,741
Ohio	975,539	1,103,818	1,215,572	1,389,170
Indiana	13,211	15,260	9,839	16,398
Illinois	565,453	579,307	601,035	785,239
Michigan	213,543	213,251	214,356	258,461
Wisconsin	133,508	116,037	158,634	246,237
Missouri	138,643	91,783	86,190	100,550
Colorado	25,291	20,877	2,678	23,588
Oregon	...	2,509	9,426	12,305
Washington	1,586	4,093	10,671	...
Totals	7,187,206	7,268,507	8,516,379	10,307,028

The total stock of pig iron at December 31, 1890, was 681,992 tons, as compared with 277,401 tons at the end of the previous year. In addition to this quantity in stock, 59,289 tons was held by the Pig Iron Storage Warrant Company.

The production of Bessemer pig iron was as shown in the following table:—

	Tons of 2000 lbs.		
	First Half of 1890.	Second Half of 1890.	Total for 1890.
New York	119,007	80,117	199,124
New Jersey	31,421	41,055	72,476
Pennsylvania	1,303,734	1,334,130	2,637,864
Maryland	63,276	81,009	144,285
North Carolina	577	1,780	2,357
West Virginia	57,433	80,875	138,308
Ohio	270,914	280,193	551,107
Illinois	318,795	385,532	704,327
Michigan	...	1,285	1,285
Missouri	39,551	29,903	69,454
Wisconsin	27,892	13,572	41,464
Colorado	8,945	12,428	21,373
Totals	2,241,545	2,341,879	4,583,424

The quantity of spiegeleisen and ferro-manganese made during the first half of 1890 was 97,907 tons of 2000 lbs., and during the second half 51,255 tons, a total of 149,162 tons for the year, as compared with 85,823 tons in 1889.

The *Iron Age** publishes statistics relating to each of the years 1885–1890, with a view to show the rapid change which has taken place during this period in the centres of the pig iron manufacture in the United States. This will be seen from the following table:—

District.	1885. Pig Iron Production.	1890. Pig Iron Production.
	Tons.	Tons.
Eastern Pennsylvania	1,235,248	2,196,256
Central West	1,278,325	3,486,901
Illinois and Winconsin	332,980	936,448
Southern States	490,998	1,447,697

During this period the production of Alabama increased nearly sixfold.

Production of Steel.—The American Iron and Steel Association publishes statistics † showing the output of steel and of rails in the United States in 1890. The production of Bessemer steel ingots increased from 2,930,204 statute tons in 1889 to no less than 3,681,728 tons in 1890, an increase of over 25 per cent. This is shown more fully in the following table, where the tons are net tons of 2000 lbs.:—

Bessemer Ingots.

States.	First Half 1890.	Second Half 1890.	Total 1890.	Total 1889.
	Net Tons.	Net Tons.	Net Tons.	Net Tons.
Pennsylvania	1,275,616	1,239,808	2,515,424	1,973,544
Illinois	386,497	462,254	848,751	740,001
Ohio	204,098	201,267	405,365	331,298
Other States	175,028	178,967	353,995	236,985
Totals	2,041,239	2,082,296	4,123,535	3,281,828
Clapp-Griffiths only	39,627	37,363	79,990	82,850

* Vol. xlvii. p. 288. † *Iron Age*, vol. xlvii. p. 373.

This output is the largest ever obtained in the United States; in 1885 it was only 1,701,762 net tons.

The following table shows the production of Bessemer steel rails, but it does not include a few thousand tons of Bessemer steel rails which were rolled in iron rolling mills from purchased blooms.

Rails.

States.	First Half 1890.	Second Half 1890.	Total 1890.	Total 1889.
	Net Tons.	Net Tons.	Net Tons.	Net Tons.
Pennsylvania	738,931	657,529	1,396,460	1,102,451
Illinois	279,441	308,096	587,537	522,054
Other States	14,286	14,905	29,191	22,194
Totals . . .	1,032,658	980,530	2,013,188	1,646,699

The total production of Bessemer steel rails by Bessemer steelworks and by iron rolling mills has been as follows in the five years preceding 1890 :—

Years.	Pennsylvania.	Illinois.	Other States.	Total.
	Net Tons.	Net Tons.	Net Tons.	Net Tons.
1885	736,522	308,742	29,843	1,075,107
1886	1,111,171	430,975	221,521	1,763,667
1887	1,276,845	728,526	348,761	2,354,132
1888	930,140	488,639	133,852	1,552,631
1889	1,141,350	522,054	27,860	1,691,264
1890	1,396,460	587,537	29,191	2,013,188

The steadily-increasing use of Bessemer steel in the United States for purposes other than the manufacture of rails has been frequently noted, but this use was much more marked in 1890 than in any preceding year except 1889. In 1890 about one-half of the Bessemer steel ingots produced in the United States were converted into rails.

Condition of the Blast Furnaces.—At January 1, 1891, the furnaces in blast numbered 302, with a weekly capacity of 167,599 tons, as compared with 333 furnaces and 174,038 tons at January 1, 1890.*

The condition of the anthracite furnaces was as follows :—

* *Iron Age*, vol. xlvii. pp. 110, 111.

Anthracite Furnaces.

Situation of Furnaces.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number out of Blast.	Capacity per Week.
			Tons.		Tons.
New York	22	8	3,061	14	3,785
New Jersey . . .	14	6	2,787	8	2,855
Spiegeleisen . . .	3	3	208	...	...
Pennsylvania—					
Lehigh Valley . .	45	32	13,336	13	4,500
Spiegeleisen . .	1	1	67	...	...
Schuylkill Valley . .	37	19	8,752	18	4,900
Upper Susquehanna Valley	17	9	3,069	8	2,840
Lebanon Valley . . .	18	10	4,411	8	2,590
Lower Susquehanna Valley	16	13	7,475	3	670
Totals . .	173	101	43,166	72	22,140

At January 1, 1890, the anthracite furnaces in blast numbered 105, with a weekly capacity of 42,857 tons. The following table shows the condition of the furnaces using bituminous coal and coke:—

Coke Furnaces.

Situation of Furnaces.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number out of Blast.	Capacity per Week.
			Tons.		Tons.
New York	5	2	1,721	3	3,016
Pennsylvania—					
Pittsburgh district . .	25	21	28,579	4	6,463
Spiegeleisen . .	1	1	896	...	...
Shenango Valley . .	19	11	7,571	8	7,610
Juniata and Conemaugh Valley . . .	17	9	5,354	8	3,650
Spiegeleisen . .	1	1	400	...	...
Youghiogheny Valley .	5	1	893	4	1,664
Miscellaneous . . .	4	1	542	3	1,746
Maryland	5	2	3,640	3	3,830
West Virginia . . .	4	2	1,967	2	1,600
Ohio—Mahoning Valley .	14	7	6,684	7	3,587
Central and Northern .	18	15	12,431	3	2,300
Hocking Valley . .	14	4	1,523	10	2,270
Hanging Rock . .	14	9	2,079	5	1,070
Indiana	2	2	376	...	...
Illinois	13	10	13,270	3	2,970
Spiegeleisen	1	1	500	...	...
Wisconsin	4	3	2,548	1	570
Missouri	6	...	...	6	3,340
Colorado	2	2	860	...	...
The South—Virginia . .	14	12	5,331	2	970
Kentucky	4	3	838	1	310
Alabama	37	12	7,592	25	14,690
Tennessee	11	9	4,640	2	1,068
Georgia	2	2	793	...	...
North Carolina . .	1	1	125	...	...
Totals . .	243	143	111,153	100	61,724

At the same date in the previous year there were 169 coke furnaces in blast, with a weekly capacity of 119,396 tons. The putting out of blast of the furnaces in the Shenango and Mahoning valleys in December 1890 reduced the furnaces in blast in 1891 from 168 at December 1 to 143 a month later, the weekly capacity being also diminished by 15,500 tons.

The condition of the charcoal blast furnaces was as follows at January 1:—

Charcoal Furnaces.

Situation of Furnaces.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number out of Blast.	Capacity per Week.
			Tons.		Tons.
New England	14	7	590	7	620
New York	8	3	364	5	523
Pennsylvania	16	5	529	11	462
Maryland	6	2	188	4	460
Virginia	18	3	177	15	720
Ohio	10	5	464	5	260
Kentucky	1	0	0	1	95
Tennessee	6	3	610	3	365
Georgia	3	0	0	3	410
Alabama	13	8	1,628	5	1,490
Michigan	27	14	4,867	13	3,630
Missouri	2	2	525	0	0
Wisconsin	6	4	1,798	2	170
Texas	2	2	310	0	0
California	1	0	0	1	120
Washington Territory	1	0	0	1	170
Oregon	1	1	230	0	0
Totals	135	59	12,280	76	9,495

At January 1, 1890, the charcoal furnaces in blast numbered 59, with a weekly capacity of 11,485 tons.

Imports of Iron and Steel.—The following table, compiled from the report of the Bureau of Statistics of the United States Treasury Department, shows that the quantities of iron and steel and iron ore imported into the United States during the year ending June 30, 1890, were as follows:—

Pig iron	146,772
Scrap iron	36,727
Scrap steel	2,132
Bar iron	32,063
Cotton ties, hoops, &c.	22,311
Steel ingots, billets, blooms, &c.	36,337

Sheet and plate iron or steel	8,489
Tin plates	90,030
Wire rods	62,347
Wire and wire rope	4,795
Anvils	1,581
Chains	793
Iron ore	1,157,395

Iron Ore in the United States.—The production of iron ore in the chief districts of the United States was as follows:—

	1889.	1890.
	Tons.	Tons.
Marquette Range	2,634,817	2,997,927
Menominee Range	1,796,764	2,289,017
Gogebic Range	2,016,391	2,845,171
Vermillion Lake	844,782	880,264
Missouri mines	233,784	188,653
Cornwall mines	769,020	686,302
New Jersey mines	482,169	477,289
Chateaugay mines	122,923	130,398
Crown Point mines	65,169	78,737
Port Henry mines	409,000	417,810
Other Lake Champlain mines	45,000	35,000
Hudson River Ore and Iron Company	54,000	72,505
Tilly Foster mines	70,889	76,949
Forest of Dean mines	12,042	23,016
Salisbury region	32,000	26,058
Cranberry mines	12,974	22,873
Inman mines	120,232	119,402
Alleghany Co.	162,322	184,640
Alabama	165,084	212,540
Totals	10,049,362	11,764,551

The total production in 1888 was 7,648,126 tons. The Lake Superior mines which produced the largest quantity of ore in 1890 were:—Norrie, Gogebic Range, 906,754 tons; Chapin, Menominee Range, 742,843 tons; and Ashland, Gogebic Range, 435,472 tons.*

Production of Manganese Ore.—Official statistics show the production of manganese ore in the United States in 1889 to have been 23,927 tons, valued at 238,939 dollars, as compared with 29,198 tons in 1888, and 34,524 tons in 1887.†

The Progress of Steel in the United States.—Mr. J. M. Swank ‡ publishes tables showing the rapid progress made in recent years by

* *Engineering and Mining Journal*, vol. li. p. 522.
† *Iron Age*, vol. xlvii. p. 964.
‡ *Ibid.*, vol. xlvii. p. 832.

the steel trade of the United States, the output having increased from 1,711,920 statute tons in 1885 to 4,277,071 tons in 1890. Of this latter quantity about 575,000 tons was open-hearth metal. Crucible steel has remained fairly constant, the output having been 64,511 tons in 1885 and 79,716 tons in 1890. The production of rolled iron and steel was as follows :—

Articles.	1888.		1889.		1890.	
	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
	Net Tons.	Net Tons.	Net Tons.	Net Tons.	Net Tons.	Net Tons.
Rails	14,252	1,557,892	10,258	1,694,610	15,548	2,095,996
Cut nails	108,505	216,174	88,904	201,634	90,307	191,740
Plates and sheets. .	469,312	213,694	471,193	331,283	505,642	401,537
Wire rods	14,571	298,770	14,460	393,053	19,798	492,153
Other rolled products .	1,805,014	473,247	2,001,570	658,394	2,189,082	743,817
Totals . .	2,411,654	2,759,777	2,586,385	3,278,974	2,820,377	3,925,243

The Steel Rail Trade of the United States.—Of the eleven Bessemer steelworks making rails in the United States in 1880 three no longer manufacture rails to an appreciable extent. The existing plants are practically only seven in number, and, with one exception, are all situated in Pennsylvania. Their annual capacity is estimated at 2,600,000 tons.*

American Rail Mills.—The *Iron Age* † publishes the following details relating to the nominal estimated capacity and to the actual shipments of rails weighing more than 56 lbs. per yard from the chief rolling mills of the United States during 1890 :—

	Estimated Capacity.	Shipments.
	Tons.	Tons.
Illinois Steel Company	925,000	413,850
Carnegie Steel Company	600,000	304,659
Cambria Steel Company	225,000	105,552
Pennsylvania Steel Company . .	200,000	115,077
Lackawanna Steel Company . .	225,000	138,737
Scranton Steel Company . . .	225,000	182,049
Bethlehem Steel Company . . .	200,000	128,262
Totals	2,600,000	1,388,186

* *Iron Age*, vol. xlvii. p. 1061. † Vol. xlvii. p. 198.

Production of Coke in the Connellsville District.—The following table shows the rapid progress in recent years of the coke industry of this district: *—

Years.	Production.	Value.
	Tons.	Dollars.
1885	4,109,331	5,876,343
1887	4,296,343	8,413,672
1888	4,971,287	5,965,544
1889	5,825,826	8,156,456
1890	6,221,618	12,904,940

Iron-Making in the Pittsburgh District.—In the district lying within a radius of forty miles from the town of Pittsburgh are twenty-four blast furnaces, and two others in course of construction.† About 10 per cent. of the total pig iron production of the United States comes from this district. The average weekly outturn of the twenty-four completed furnaces is 31,720 tons of 2000 lbs. The two new furnaces were expected to be in blast early in 1891, and these are estimated to be of a capacity of 167,800 tons of pig iron per annum.

Blast Furnaces in Ohio.—The outturn of the blast furnaces of Lawrence County, Ohio, amounted to 70,421 tons in 1890 as compared with 61,180 tons in 1889. The output of the three larger furnaces was as follows: ‡—

Name.	Production.
	Tons.
Hamilton	17,802
"Iron and Steel"	14,000
Belfont	22,000

In 1887 the output of Lawrence County reached its maximum, 93,254 tons. There has, therefore, been a considerable diminution since that date.

The Coal-Mining Industry of Alabama.—A preliminary report issued by the Superintendent of the Eleventh Census of the United States contains some interesting information as to the coal-mining industry in the State of Alabama. The coalfields of Alabama form the southern extremity of the great Appalachian coalfields, the northern limit of which lies along the Western New York and Pennsylvania State

* *Iron Age*, vol. xlvii. p. 105. † *Ibid.*, vol. xlvi. p. 883.
‡ *Ibid.*, xlvii. p. 111.

line, and extends south-westward through portions of Pennsylvania, Maryland, West Virginia, Virginia, Ohio, Kentucky, Tennessee, Alabama, and Georgia. The State Geological Survey of Alabama estimates that the coal deposits embrace an area of 8660 square miles, although actual mining operations are conducted in but ten out of nineteen counties in which coal deposits are known to exist. The coals of Alabama embrace all the bituminous varieties. Coal-mining was begun in this State about the year 1853, but the total output which was produced for local consumption did not reach 100,000 tons until the year 1876. The production for the census year 1880 was 323,972 tons, valued at £95,382 at the mines. The growth of the industry thenceforward has been almost phenomenal, the product for the calendar year 1889 being 3,378,484 nett tons, valued at £741,485. The average price received at the mines, per ton of 2000 lbs., was 4s. 5d. The total number of regular establishments equipped for the preparation and shipment of coal was forty-four. Besides these there were twenty-two small banks and local mines. The disposition of the total product of 3,378,484 tons was as follows:—Loaded at mines for shipment by rail and boat, 2,266,839 tons; used by employés and sold to local trade, 58,684; used for steam and heat at mines, 70,690; made into coke, 982,271. Of the amount shown above as loaded at mines for shipment, 1,868,596 tons was delivered for consumption within the State of Alabama. The average number of persons employed during the year was 6762, and the amount of wages paid was £635,071. The average number of days when the mines were shipping coal was 196 during the year 1889.

Coal-Mining in Indiana.—The Government Inspector for the State of Indiana reports that the output of coal is now over 8,000,000 tons per annum from seventy-two coal mines situated in eleven counties. The total number of miners is 6550. The average cost of mining is 2s. 6d. a ton.

Anthracite in Pennsylvania.—The Superintendent of the Eleventh Census of the United States has just issued a report upon the anthracite coalfields of Pennsylvania. The report, which has been prepared by the special agent in charge of the coal statistics, shows the situation of the anthracite fields, with the districts, mines, and production for the calendar year 1889, shipments by decades, production by counties, and a complete directory of the anthracite collieries. The anthracite coal-

fields of Pennsylvania are situated in the eastern part of the state, and extend about equal distances north and south of a line drawn through the middle of the state from east to west, in the counties of Carbon, Columbia, Dauphin, Lackawanna, Luzerna, Northumberland, Schuylkill, Sullivan, and Susquehanna. According to the report the total production of anthracite coal in the state during the calendar year 1889 was 40,665,152 statute tons valued at the mines at £13,143,000, or an average of 6s. 9d. per ton, including all sizes sent to market. The quantity reported by the transportation companies as actually carried to market, which is the usual basis for statistics of shipments, was 35,407,710 tons during the year 1889; 1,329,580 tons were used by employes and sold to local trade in the vicinity of the mines, and 3,518,696 tons was reported as consumed for steam and heating purposes in and about the mines. The item of colliery consumption, however, is somewhat indefinite, the coal being taken either from the current mining or from screenings, and used where needed, often without preparation. The average number of days worked during the year 1889 by all the collieries was 194. The suspension of mining during periods aggregating about one-third of the year was caused mainly by the inability of the market to absorb a larger product. The number of persons employed during the year, including superintendents, engineers, and clerical force, was 125,229, as against 70,669 employed in 1879, the year when the tenth census was taken. The total amount paid in wages to all classes during the year was 39,152,124 dollars; in 1879 the amount paid was 22,664,055 dollars. The total number of regular establishments or breakers equipped for the preparation and shipment of coal was 342, 19 of which were idle during the year. Besides these, there were 49 small diggings and washeries, supplying local trade. There were also eighteen new establishments in course of construction. The largest actual shipment during any year in the history of the trade was made in 1888, being 38,145,178 statute tons. The largest actual shipment for any one month was 4,187,527 tons, in October 1888. The shipments of anthracite coal from Pennsylvania, since 1820, have been as follows:—From 1820 to 1859, inclusive, 83,835,841 tons; from 1860 to 1869, 107,092,918 tons; from 1870 to 1879, 195,714,376 tons; from 1880 to 1889, 315,523,013 tons—or a total of 702,166,148 tons.

The Cost of Production of Iron and Steel.—This forms the subject of a United States official report by Mr. C. D. Wright,* Com-

* *Iron Age*, vol. xlvii. pp. 370–373.

missioner of Labour. This report, which has recently been submitted to Congress, is the result of several years of careful investigation both in the United States and in Europe, and is based on an examination of the books of manufacturers and the inquiries of expert special agents of the Department of Labour. The report was required in connection with changes in the import duties on iron and steel. It treats (1) of the cost of production, (2) of the rates of wages, time, earnings, and efficiency of the labour employed, and (3) of the cost of living and total earnings and expenditures of the workpeople.

In treating of the cost of production, all expenses for insurance, interest, depreciation, and royalty have been excluded from consideration, as also have the charges for the freight of the product to the place of free delivery. These facts have been collected, and are given in the report, but are not included in the principal tables. The essential elements of cost which are included are the cost of materials, labour, salaries of officials and clerks, supplies, repairs, and taxes.

The details given are based on information supplied by no less than 618 establishments manufacturing various kinds of iron or steel, or their more finished products. The details relating to pig iron were obtained from 118 ironworks, about two-thirds of which are in the United States.

The Cost of Manufacturing Pig Iron.

Locality.	Cost of Material.	Labour.	Total Cost.
	Dollars.	Dollars.	Dollars.
Northern United States	17.728	3.589	23.165
Northern ,, ,,	13.223	1.194	15.202
Southern ,, ,,	7.757	1.461	10.279
Northern ,, ,,	11.991	0.975	13.584
Northern ,, ,,	11.663	1.364	13.433
Europe	9.559	0.418	10.394
Europe	12.228	0.912	13.434
Great Britain	9.230	0.601	10.290
Great Britain	9.308	0.743	10.729
Europe	14.219	0.719	15.075
Europe	6.785	0.470	7.736
Northern United States	12.267	2.135	15.258
Great Britain	6.454	0.618	7.677
Northern United States	11.147	1.166	12.820
Southern ,, ,,	7.173	1.816	9.634
Southern ,, ,,	7.202	2.608	10.267
Southern ,, ,,	8.877	1.218	10.822
Southern ,, ,,	8.164	0.595	9.623
Europe	9.885	1.414	12.070
Great Britain	9.529	0.769	10.893
Europe	9.061	0.711	11.107
Europe	7.327	0.755	8.765

A comparison of the cost of materials used in the Northern and Southern districts of the United States shows that the difference in favour of the South in the cost of ore and of coal is very great, although the difference, so far as the ore is concerned, is partially offset by its comparatively higher percentage of iron in the Northern district. The ore used in the Northern district costs per ton an average of 4.401 dollars; the cinder, scrap, &c., 2.631 dollars; the limestone, 79.8 cents; the coke, 3.014 dollars, and the coal, 2.695 dollars. The cost in the Southern district for the ore is 1.513 dollar; the cinder, scrap, &c., 1.031 dollar; the limestone, 70.1 cent; the coke, 3.084 dollar, and the coal, 1.566 dollar.

The following table illustrates the comparative cost of different items in the Northern and Southern districts of the United States:—

Summary of Cost per Ton of all Elements in Making Pig Iron.

	Northern District.	Southern District.
Establishments reporting the facts required for the statements below	26	24
Cost of all materials used in these establishments, dollars	6,387,622	5,450,459
Cost of labour, &c., dollars	1,199,918	1,515,995
Cost of all elements, dollars	7,587,540	6,966,454
Tons of product	544,377	647,728
Average cost of all materials per ton of product, dollars	11.734	8.414
Average cost of labour, &c., per ton of product, dollars	2.204	2.341
Average cost of all elements per ton of product, dollars	13.938	10.755

With reference to the total cost of the ton of pig iron, from the mining of the materials to the finished product, the following details are given:—

Total Cost per Ton of Pig Iron.

Kind of Iron.	Direct Labour.	Officials and Clerks.	Supplies, Repairs, and Taxes.	Transport to Point where Used.	Difference between Foregoing Actual Costs and Costs as Charged by Blast Furnaces.	Total.
	Dollars.	Dollar.	Dollars.	Dollars.	Dollars.	Dollars.
Northern District, U.S.A.						
Bessemer . . .	9.446	0.175	1.552	1.697	1.101	13.971
,, . . .	4.412	0.220	1.359	5.316	3.922	15.229
,, . . .	5.733	0.510	2.108	4.992	3.134	16.477
,, . . .	5.569	0.327	1.493	5.322	1.790	14.501
,, . . .	5.274	0.398	1.389	3.543	5.063	15.667
Foundry . . .	3.701	...	...	6.040	3.944	13.685
Hot-blast charcoal .	6.737	...	...	6.311	3.159	16.207
Southern District, U.S.A.						
Run of furnace . .	7.293	0.191	0.667	0.779	1.003	9.933
,, . .	5.884	0.285	1.220	1.270	0.502	9.161
,, . .	4.312	0.453	1.232	1.555	2.071	9,623
,, . .	7.598	0.269	1.181	0.360	0.219	9.627
,, . .	6.958	0.351	1.292	1.180	0.819	10.600
Great Britain—						
Bessemer . . .	3.329	0.148	1.543	3.237	1.739	9.996

Details relating to the cost of production of steel rails were not so readily obtainable, but the following table gives details relating to thirteen representative establishments in the United States, the United Kingdom, and on the Continent of Europe:—

The Cost of the Production of the Ton of Steel Rails.

No.	Locality.	Net Cost of Materials.	Labour.	Total Cost.
		Dollars.	Dollars.	Dollars.
1	United States	21.109	1.540	24.799
2	United States	25.114	1.382	27.687
3	Continent of Europe . .	17.672	1.043	19.576
4	Continent of Europe . .	18.066	2.519	22.184
5	Continent of Europe . .	18.066	4.641	25.652
6	Continent of Europe . .	18.231	2.583	23.121
7	Continent of Europe . .	18.103	2.689	23.190
8	Continent of Europe . .	18.664	2.974	23.743
9	Continent of Europe . .	18.808	1.028	22.439
10	Continent of Europe . .	19.880	2.160	26.711
11	Great Britain	18.058	2.548	21.907
12	Great Britain	16.395	1.368	18.588
13	Great Britain	17.159	1.583	20.178

In the establishments Nos. 1, 3, and 12, fairly representing their respective countries, the iron ore used in the manufacture of the ton of rails amounted respectively to 4137, 5701, and 5127 lbs.; the entire

direct labour cost of production in these establishments was 11.59 dollars per ton in the United States, 7.81 dollars in the United Kingdom, and 8.10 dollars on the continent of Europe.

The average daily earnings in the United States were found to vary from 1.22 dollar to 2.03 dollars, while on the continent of Europe they varied from 0.64 to 0.70 dollar.

The following table is given showing the relative cost of producing a ton of pig iron in money, and in working hours in different establishments in the Northern and Southern districts of the United States :—

The Labour Cost of Pig Iron.

Locality.	Total Product in Tons.	Money Cost per Ton.	Time Cost per Ton in Hours.
		Dollars.	
Northern United States	8,296	2.069	16.11
Northern " "	29,390	1.983	14.41
Northern " "	32,633	1.268	8.92
Northern " "	2,447	1.990	14.76
Southern " "	34,506	1.359	11.34
Southern " "	32,921	1.476	13.49
Southern " "	11,855	1.311	12.89

A number of works furnished details showing the average earnings per man per hour, and the average product in tons per man per hour, and some of these are given in the following table :—

Average Earnings and Product of Pig Iron.

Locality.	Average Earnings per Hour.	Average Product per Hour in Tons.
	Dollar.	Dollar.
Northern United States	0.142	0.094
Northern " "	0.134	0.085
Northern " "	0.187	0.162
Northern " "	0.095	0.067
Northern " "	0.140	0.081
Northern " "	0.163	0.091
Southern " "	0.131	0.072
Southern " "	0.115	0.044
Southern " "	0.131	0.076
Southern " "	0.121	0.154
Europe	0.059	0.082
Europe	0.045	0.105
Europe	0.051	0.067
Great Britain	0.058	0.079
Great Britain	0.100	0.130

Details relating to the cost of living were obtained from 3260 families, and these and a number of other statistics of great interest are given in the report, which forms a volume of about 1200 pages.

The Cost of Steel Rails in the United States.—The *Iron Age* * publishes details showing the average cost per ton of the coal and pig iron used at a leading rail mill in the United States, together with the selling price of the pig iron for each of the months January 1881 to December 1890. The following is an abstract of these prices for the month of January :—

Year.	Coal.	Pig Iron.	Rails.
	Dollar.	Dollars.	Dollars.
1881	1.23	24.34	41.34
1882	1.42	22.20	42.05
1883	1.33	27.40	42.32
1884	1.14	16.89	31.86
1885	1.05	15.92	27.37
1886	1.19	16.36	27.32
1887	1.20	18.90	31.23
1888	1.24	17.34	35.45
1889	1.09	15.59	26.96
1890	1.05	15.92	27.83
Dec. 1890	1.23	15.68	31.01

Iron Manufacture at Marquette.—Mr. R. A. Parker † reports on the feasibility of the production of iron at Marquette. Coal can be brought from Connellsville to Marquette, and coked there at a cost of not exceeding £1, 3s., and Bessemer pig iron would cost £2, 13s. 3d. per ton for materials. The question seems to depend on the rates of carriage, as most of the vessels which take ore from the port have to return empty, and could therefore be utilised to carry coal. The question of using leaner ores in steel manufacture is also considered.

XV.—*COMPARATIVE TABLES.*

Comparative Production of Coal.—H. Courist ‡ gives the following table, showing comparatively the quantity of coal raised by each workmen employed in the United Kingdom, Belgium, France, and Germany :—

* Vol. xlvii. p. 834. † *Engineering and Mining Journal*, vol. l. p. 688.
‡ *Stahl und Eisen*, vol. xi. p. 233.

Year.	U. Kingdom.		Belgium.		France.		Germany.	
	For each Miner.	For each Person Employed.	For each Miner.	For each Person Employed.	For each Miner.	For each Person Employed.	For each Miner.	For each Person Employed.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1882	428	345	221	167	265	190	346	274
1888	387	317	246	184	305	215	425	317
Difference in 1888 .	– 41	– 28	+ 25	+ 17	+ 40	+ 25	+ 79	+ 43

It will be observed that the United Kingdom is the only country in which the miner raises less coal now than in 1882.

Progress of the Basic Bessemer Process.—The total make of steel and ingot iron by the basic process during 1890 shows an increase over the previous year of 328,531 tons. The total production from the introduction of this process up to date is 13,448,000 tons. The production by countries is as follows:—

Countries.	1890.		1889.	
	Total.	With under 0·17 per cent. Carbon.	Total.	With under 0·17 per cent. Carbon.
	Tons.	Tons.	Tons.	Tons.
England	503,400	351,404	493,919	348,828
Germany and Luxemburg . .	1,493,157	1,138,241	1,305,887	1,060,416
Austria	202,315	114,857	175,755	124,907
France	240,638	175,550	222,392	159,271
Belgium, Russia, and U. States .	163,573	111,963	76,599	71,217
Totals . .	2,603,083	1,892,015	2,274,552	1,764,639

With this about 623,000 tons of slag, containing about 36 per cent. of calcium phosphate, was produced, and mostly used as a fertiliser. There was a considerable falling off in consumption for this purpose, as 700,000 tons was used in 1889.

Relative Iron and Steel Production of the United Kingdom and the United States.—In a supplementary diagram the *Iron Age* * shows graphically the relative progress of the iron and steel trades

* Vol. xlvii. p. 245.

of the United Kingdom and the United States during each of the years 1860–1890. It is hard to grasp how rapid has been the progress in the United States except by examining a graphic arrangement such as that referred to. From it, too, will be seen that the conditions of trade in the two countries have been almost identical in any year throughout the period 1860–1885. Since this latter date the progress of the iron and steel industries of the United States have been enormous, the production of pig iron having increased from less than 4,600,000 tons to about 10,000,000, and of Bessemer steel from less than 2,000,000 to nearly 4,000,000 tons.

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